

Technology for the United States Navy and Marine Corps, 2000-2035

Becoming a 21st-Century Force

VOLUME 4 Human Resources

NAVAL STUDIES BOARD
NATIONAL RESEARCH COUNCIL

*"Technology for the U.S. Navy and Marine Corps
2000 - 2035 Becoming a 21st Century Force"*

PLEASE CHECK THE APPROPRIATE BLOCK BELOW:

AO#499-05-0372 Vol 4

☐ _____ copies are being forwarded. Indicate whether Statement A, B, C, D, E, F, or X applies.

☒ **DISTRIBUTION STATEMENT A:**
APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED - *all 9 volumes*

☐ **DISTRIBUTION STATEMENT B:**
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES ONLY; (Indicate Reason and Date). OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ **DISTRIBUTION STATEMENT C:**
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND THEIR CONTRACTORS; (Indicate Reason and Date). OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ **DISTRIBUTION STATEMENT D:**
DISTRIBUTION AUTHORIZED TO DoD AND U.S. DoD CONTRACTORS ONLY; (Indicate Reason and Date). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ **DISTRIBUTION STATEMENT E:**
DISTRIBUTION AUTHORIZED TO DoD COMPONENTS ONLY; (Indicate Reason and Date). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ **DISTRIBUTION STATEMENT F:**
FURTHER DISSEMINATION ONLY AS DIRECTED BY (Indicate Controlling DoD Office and Date) or HIGHER DoD AUTHORITY.

☐ **DISTRIBUTION STATEMENT X:**
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND PRIVATE INDIVIDUALS OR ENTERPRISES ELIGIBLE TO OBTAIN EXPORT-CONTROLLED TECHNICAL DATA IN ACCORDANCE WITH DoD DIRECTIVE 5230.25, WITHHOLDING OF UNCLASSIFIED TECHNICAL DATA FROM PUBLIC DISCLOSURE, 6 Nov 1984 (Indicate date of determination). CONTROLLING DoD OFFICE IS (Indicate Controlling DoD Office).

☐ This document was previously forwarded to DTIC on _____ (date) and the AD number is _____.

☐ In accordance with provisions of DoD instructions, the document requested is not supplied because:

☐ It will be published at a later date. (Enter approximate date, if known).

☐ Other. (Give Reason)

DoD Directive 5230.24, "Distribution Statements on Technical Documents," 18 Mar 87, contains seven distribution statements, as described briefly above. Technical Documents must be assigned distribution statements.

MARY GORDON

Print or Type Name

212/334-3526

Mary Gordon 2/1/99

Technology for the United States Navy and Marine Corps, 2000-2035

Becoming a 21st-Century Force

VOLUME 4 Human Resources

Panel on Human Resources
Committee on Technology for Future Naval Forces
Naval Studies Board
Commission on Physical Sciences, Mathematics, and Applications
National Research Council

1 9 9 9 0 2 1 9 0 0 5

NATIONAL ACADEMY PRESS
Washington, D.C. 1997

DTIC QUALITY INSPECTED 4

499-05-0372

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

This work was performed under Department of the Navy Contract N00014-96-D-0169/0001 issued by the Office of Naval Research under contract authority NR 201-124. However, the content does not necessarily reflect the position or the policy of the Department of the Navy or the government, and no official endorsement should be inferred.

The United States Government has at least a royalty-free, nonexclusive, and irrevocable license throughout the world for government purposes to publish, translate, reproduce, deliver, perform, and dispose of all or any of this work, and to authorize others so to do.

Copyright 1997 by the National Academy of Sciences. All rights reserved.

Copies available from:

Naval Studies Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America

PANEL ON HUMAN RESOURCES

ROBERT J. MURRAY, Center for Naval Analyses, *Chair*
J. DEXTER FLETCHER, Institute for Defense Analyses, *Vice Chair*
PAUL R. CHATELIER, Defense Modeling and Simulation Office
DONALD J. CYMROT, Center for Naval Analyses
WARREN S. GRUNDFEST, Cedars-Sinai Medical Center
LEE D. HEIB, Yuma, Arizona
ELYSE W. KERCE, Madison, Alabama
REUVEN LEOPOLD, Syntek
R. BOWEN LOFTIN, University of Houston
JAMES A. MARTIN, Bryn Mawr College
JOSEPH M. ROSEN, Dartmouth-Hitchcock Medical Center
HARRISON SHULL, Monterey, California
NORMAN H. SMITH, Linden, Virginia
J. PACE VanDEVENDER, Prosperity Institute
JOSEPH ZEIDNER, George Washington University

Navy Liaison Representatives

CDR MARK BURGUNDER, USN, Office of the Chief of Naval Operations,
N752
MS. SANDRA CRUM, Office of the Chief of Naval Operations, N464
CDR CHARLES ENGLISH, USN, Office of the Chief of Naval Operations,
N931
CDR GILBERT GIBSON, USN, Office of the Chief of Naval Operations,
N971P
CDR CHARLES GUNN, USN, Bureau of Medicine
LCDR WILLIAM JONSON, USN, Office of the Chief of Naval Operations,
N752
CDR BARBARA KOROSSEC, USN, Office of the Chief of Naval Operations,
N122B
CDR DAVID SORANNO, USN, Office of the Chief of Naval Operations,
N712
DR. DANIEL STABILE, Office of the Chief of Naval Operations, PERS6D

Consultants

LEE M. HUNT
SIDNEY G. REED, JR.
JAMES G. WILSON

Staff

RONALD D. TAYLOR, Director, Naval Studies Board

PETER W. ROONEY, Program Officer

SUSAN G. CAMPBELL, Administrative Assistant

MARY G. GORDON, Information Officer

CHRISTOPHER A. HANNA, Project Assistant

COMMITTEE ON TECHNOLOGY FOR FUTURE NAVAL FORCES

DAVID R. HEEBNER, Science Applications International Corporation
(retired), *Study Director*

ALBERT J. BACIOCCO, JR., The Baciocco Group, Inc.

ALAN BERMAN, Applied Research Laboratory, Pennsylvania State University

NORMAN E. BETAQUE, Logistics Management Institute

GERALD A. CANN, Raytheon Company

GEORGE F. CARRIER, Harvard University

SEYMOUR J. DEITCHMAN, Institute for Defense Analyses (retired)

ALEXANDER FLAX, Potomac, Maryland

WILLIAM J. MORAN, Redwood City, California

ROBERT J. MURRAY, Center for Naval Analyses

ROBERT B. OAKLEY, National Defense University

JOSEPH B. REAGAN, Saratoga, California

VINCENT VITTO, Lincoln Laboratory, Massachusetts Institute of Technology

Navy Liaison Representatives

RADM JOHN W. CRAINE, JR., USN, Office of the Chief of Naval
Operations, N81 (as of July 4, 1996)

VADM THOMAS B. FARGO, USN, Office of the Chief of Naval Operations,
N81 (through July 3, 1996)

RADM RICHARD A. RIDDELL, USN, Office of the Chief of Naval
Operations, N91

CDR DOUGLASS BIESEL, USN, Office of the Chief of Naval Operations,
N812C1

PAUL G. BLATCH, Office of the Chief of Naval Operations, N911E

Marine Corps Liaison Representative

LtGen PAUL K. VAN RIPER, USMC, Marine Corps Combat Development
Command

Consultants

LEE M. HUNT

SIDNEY G. REED, JR.

JAMES G. WILSON

Staff

RONALD D. TAYLOR, Director, Naval Studies Board

PETER W. ROONEY, Program Officer

SUSAN G. CAMPBELL, Administrative Assistant

MARY G. GORDON, Information Officer

CHRISTOPHER A. HANNA, Project Assistant

NAVAL STUDIES BOARD

DAVID R. HEEBNER, Science Applications International Corporation
(retired), *Chair*

GEORGE M. WHITESIDES, Harvard University, *Vice Chair*

ALBERT J. BACIOCCO, JR., The Baciocco Group, Inc.

ALAN BERMAN, Applied Research Laboratory, Pennsylvania State
University

NORMAN E. BETAQUE, Logistics Management Institute

NORVAL L. BROOME, Mitre Corporation

GERALD A. CANN, Raytheon Company

SEYMOUR J. DEITCHMAN, Institute for Defense Analyses (retired), *Special
Advisor*

ANTHONY J. DeMARIA, DeMaria ElectroOptics Systems, Inc.

JOHN F. EGAN, Lockheed Martin Corporation

ROBERT HUMMEL, Courant Institute of Mathematical Sciences, New York
University

DAVID W. McCALL, Far Hills, New Jersey

ROBERT J. MURRAY, Center for Naval Analyses

ROBERT B. OAKLEY, National Defense University

WILLIAM J. PHILLIPS, Northstar Associates, Inc.

MARA G. PRENTISS, Jefferson Laboratory, Harvard University

HERBERT RABIN, University of Maryland

JULIE JCH RYAN, Booz, Allen and Hamilton

HARRISON SHULL, Monterey, California

KEITH A. SMITH, Vienna, Virginia

ROBERT C. SPINDEL, Applied Physics Laboratory, University of
Washington

DAVID L. STANFORD, Science Applications International Corporation

H. GREGORY TORNATORE, Applied Physics Laboratory, Johns Hopkins
University

J. PACE VanDEVENDER, Prosperity Institute

VINCENT VITTO, Lincoln Laboratory, Massachusetts Institute of Technology

BRUCE WALD, Arlington Education Consultants

Navy Liaison Representatives

RADM JOHN W. CRAINE, JR., USN, Office of the Chief of Naval
Operations, N81 (as of July 4, 1996)

VADM THOMAS B. FARGO, USN, Office of the Chief of Naval Operations,
N81 (through July 3, 1996)

RADM RICHARD A. RIDDELL, USN, Office of the Chief of Naval
Operations, N91

RONALD N. KOSTOFF, Office of Naval Research

Marine Corps Liaison Representative

LtGen PAUL K. VAN RIPER, USMC, Marine Corps Combat Development
Command

RONALD D. TAYLOR, Director

PETER W. ROONEY, Program Officer

SUSAN G. CAMPBELL, Administrative Assistant

MARY G. GORDON, Information Officer

CHRISTOPHER A. HANNA, Project Assistant

**COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS,
AND APPLICATIONS**

ROBERT J. HERMANN, United Technologies Corporation, *Co-Chair*
W. CARL LINEBERGER, University of Colorado, *Co-Chair*
PETER M. BANKS, Environmental Research Institute of Michigan
LAWRENCE D. BROWN, University of Pennsylvania
RONALD G. DOUGLAS, Texas A&M University
JOHN E. ESTES, University of California at Santa Barbara
L. LOUIS HEGEDUS, Elf Atochem North America, Inc.
JOHN E. HOPCROFT, Cornell University
RHONDA J. HUGHES, Bryn Mawr College
SHIRLEY A. JACKSON, U.S. Nuclear Regulatory Commission
KENNETH H. KELLER, University of Minnesota
KENNETH I. KELLERMANN, National Radio Astronomy Observatory
MARGARET G. KIVELSON, University of California at Los Angeles
DANIEL KLEPPNER, Massachusetts Institute of Technology
JOHN KREICK, Sanders, a Lockheed Martin Company
MARSHA I. LESTER, University of Pennsylvania
THOMAS A. PRINCE, California Institute of Technology
NICHOLAS P. SAMIOS, Brookhaven National Laboratory
L.E. SCRIVEN, University of Minnesota
SHMUEL WINOGRAD, IBM T.J. Watson Research Center
CHARLES A. ZRAKET, Mitre Corporation (retired)

NORMAN METZGER, Executive Director

Preface

This report is part of the nine-volume series entitled *Technology for the United States Navy and Marine Corps, 2000-2035: Becoming a 21st-Century Force*. The series is the product of an 18-month study requested by the Chief of Naval Operations. To carry out this study, eight technical panels were organized under the Committee on Technology for Future Naval Forces to examine all of the specific technical areas called out in the terms of reference.

On November 28, 1995, the Chief of Naval Operations (CNO) requested that the National Research Council initiate (through its Naval Studies Board) a thorough examination of the impact of advancing technology on the form and capability of the naval forces to the year 2035. The terms of reference for the study specifically asked for an identification of "present and emerging technologies that relate to the full breadth of Navy and Marine Corps mission capabilities," with specific attention to "(1) information warfare, electronic warfare, and the use of surveillance assets; (2) mine warfare and submarine warfare; (3) Navy and Marine Corps weaponry in the context of effectiveness on target; [and] (4) issues in caring for and maximizing effectiveness of Navy and Marine Corps human resources." Ten specific technical areas were identified to which attention should be broadly directed. The CNO's letter of request with the full terms of reference is given in Appendix A of this report.

The Panel on Human Resources was constituted to address items 7, 8, and 9 in the terms of reference for the overall study:

7. In the future, Navy and Marine Corps personnel may be called upon to serve in non-traditional environments and face new types of threats. Application of new technologies to the Navy's medical and health care delivery systems should be assessed with these factors, as well as joint and coalition opera-

tions, reduced force and manpower levels, and the adequacy of specialized training in mind.

8. Efficient and effective use of personnel will be of critical importance. The impact of new technologies on personnel issues, such as education and training, recruitment, retention and motivation, and the efficient marriage of personnel and machines should be addressed in the review. A review of past practices in education and training would provide a useful adjunct.

9. Housing, barracks, MWR [morale, welfare, and recreation] facilities, commissaries, child care, etc. are all part of the Quality of Life (QOL) of naval personnel. The study should evaluate how technology can be used to enhance QOL and should define militarily meaningful measures of effectiveness (for example, the impact on Navy readiness).

The terms of reference charged the panel with conducting a very broad review of human resource issues. Within the context of its charge, the panel focused on the following four areas:

1. *Manpower and personnel.* How can technology improve performance while reducing manning requirements at sea and ashore?
2. *Education and training.* How can technology increase the effectiveness and stabilize the cost of education and training?
3. *Medical care.* How can technology provide both protection and rapid medical care for sailors and marines in the emerging environments for naval operations?
4. *Quality of life.* How can technology improve the quality of life for sailors and marines at work, at sea, and at home?

The panel reviewed current practices and processes in these four areas and projected both requirements and the candidate technologies that would enable the Navy to more effectively meet these requirements by the year 2035. The panel sought the best and most up-to-date information it could find to help understand how activities in these four areas are accomplished now and how they are likely to be affected by emerging concepts of operations, human resource trends, and new technologies. The panel surveyed the practices of major corporations and other non-Defense Department sources to see how human resources are managed in the nondefense sector. Finally, the panel sought advice and information on trends and desirable outcomes for Navy and Marine Corps capabilities in these four areas of activity.

Panel membership included expertise in human factors engineering, education and training, biomedical engineering, psychology, psychiatry, surgery and internal medicine, telecommunications and information science, management science, economics, and operational experience managing large manpower programs.

Contents

EXECUTIVE SUMMARY	1
1 HUMAN RESOURCE ISSUES FOR THE NAVY AND MARINE CORPS	16
Recruiting People of Above-average Ability, 17	
Selective Recruiting Through More Lateral Entries, 18	
Keeping People Longer, 19	
Assessing Today's Quality, 21	
Looking to the Future, 24	
2 EDUCATION AND TRAINING	36
National Issues, 36	
Naval Force Issues, 38	
Military Training, 40	
Training Challenges, 41	
Technology Effectiveness, 44	
Budgetary Considerations, 50	
Flag and General Officer Training, 54	
Training Modernization, 55	
Training Summary, 57	
3 COMBAT MEDICINE	63
The Combat Medical Environment, 63	
Protection and Prevention, 64	
Casualty Assessment, Care, and Evacuation, 66	
Medical Technology, 67	

4	QUALITY OF LIFE	72
	The Role of Quality of Life, 74	
	Assumptions About the Navy in the 21st Century, 75	
	Impact of Technology, 76	
	Impact of Demographic and Societal Changes, 78	
	Quality-of-Life Research, 79	
	Measures of Quality of Life, 83	
	Quality-of-Life Priorities for the Future Navy and Marine Corps, 85	
5	DEVELOPMENT AND MAINTENANCE OF HUMAN PERFORMANCE	87
APPENDIXES		
A	Terms of Reference	93
B	Acronyms and Abbreviations	98

Executive Summary

INTRODUCTION

As the 20th century closes, the United States is pursuing a worldwide foreign policy. It is one of the few countries, and in many instances the only country, capable of leading in international politics. That the U.S. armed forces are a principal tool of this leadership will surely be as true in 2035 as it is today.

Many features of the present world order are likely to exist in 2035, but it is also likely that the United States will face, in one form or another, competition for world leadership and possibly an emerging, powerful adversary. The armed forces will be no less important in 2035 than they are today, and their capabilities and competence may well become more important. One difference between 1997 and 2035 will be the dramatic advances in technology and its applications occurring over these years.

Such advances in technologies represent both significant challenges and opportunities. The Navy and the Marine Corps must adapt to these advances and make the most of them if they are to meet their responsibilities for leadership among the world's military organizations. These adaptations must not be limited to the acquisition of materiel. Without the people—the human competence—needed to operate, maintain, deploy, and command the naval force materiel assets, investment in these assets will return far less than what is intended and may, in fact, be wasted.

Modernization should also include Navy and Marine Corps processes for recruiting, training, educating, managing, and supporting people. These initiatives should keep pace with investments made to apply technology elsewhere.

They cannot wisely be shortchanged in favor of materiel acquisition. They are modest compared to investments in materiel and will support themselves. Most importantly, they will yield significant advances in naval force effectiveness.

The criticality of human performance to Navy and Marine Corps operations and its effective development and management were recognized in the terms of reference for the original Navy-21 study, *Implications of Advancing Technology for Naval Operations in the Twenty-First Century*.¹ This earlier study foresaw the following trends:

- Increasing system complexity;
- Long operational periods away from home bases;
- High demand for high-aptitude people;
- A smaller, more mature, and more proficient force whose members are retained longer in the Service;
- Increasing need for reliable, easily used equipment to reduce manning requirements;
- Increasing substitution of intelligent machines for people;
- Increasing use of advanced technology for training; and
- Increasing use of embedded training to distribute training to distributed forces.

Many of these trends are carried forward into the current report, as are the concern with human performance and the necessity of ensuring human competence in our naval forces. The present study seeks, in part, to update Navy-21 findings in the light of technological and strategic changes that have occurred in the intervening 10 years. It also responds to additional tasking in the areas of quality of life and medical care.

APPROACH TO THIS STUDY

The most difficult aspect of the panel's task involved anticipating developments and requirements in the year 2035. How might the United States have developed training for World War II before fighting World War I? How might our nation have prepared for the Korean War in, say, 1920?

Revolutionary breakthroughs are rare and, by definition, difficult to foresee. It is possible, however, to extrapolate developments that are evolving from current technology and global trends. The Panel on Human Resources sought to determine what might be done now to encourage the evolution of capabilities and practices that will ensure the efficient acquisition and management of human

¹Naval Studies Board. 1988. *Navy-21: Implications of Advancing Technology for Naval Operations in the Twenty-First Century, Volume I: Overview*, National Academy Press, Washington, D.C.

resources needed by the Navy and Marine Corps to meet operational requirements in 2035. The panel specifically tried to identify areas in which relatively small investments are likely to yield substantial returns.

Some aspects of the operational environment likely to exist in 2035 could have a substantial impact on the development and management of human resources and thus are emphasized here. The panel assumed the following:

- Service personnel will be inundated with technology and information.
- Fewer people will be required or available for Navy and Marine Corps missions, but the investment in those people will be greater. Individuals will have more training, autonomy, decision-making responsibility, and military value.
- Many operations will involve joint and/or multinational forces. Service personnel will have to deal successfully with organizational and cultural diversity and to coordinate their operations with both military and civilian organizations.
- Units will be dispersed, but most operations will require rapid organizing of tasks and training for preparation of forces. The Department of the Navy will require the capability to determine quickly and accurately the location and capabilities of units and individuals as well as their specialized skills and knowledge.
- Responsibilities for missions other than war (i.e., peacekeeping, peace imposition, disaster relief, and counterterrorism) will continue. These missions will require rapid, ad hoc preparations for unusual and unforeseen contingencies.
- Biological and chemical threats will increase.

STRATEGIC OBJECTIVES IDENTIFIED

Eight Strategic Objectives

On the basis of the considerations noted above and in response to its charge, the panel developed eight strategic objectives that it believes require and deserve the attention of the Chief of Naval Operations (CNO) if our nation's naval forces are to develop and maintain the human resources—the human performance and competence—they will need to meet the challenges of the 21st century. The eight strategic objectives, and the chapters in which they are discussed, are as follows:

1. Recruit a higher proportion of people with above-average abilities, including already trained people through lateral entry, and retain high performers for longer periods (Chapter 1).
2. Reduce the numbers of sailors required on ships and ashore, and increase their performance by investing in their professional development and personal well-being (Chapter 1).
3. Emphasize education for officers as an essential part of career development, especially education in science and engineering (Chapter 2).

4. Invest more in the conversion of conventional forms of training to technology-based, distributed training (Chapter 2).
5. Provide for significant advances in the development and application of medical technologies for reducing combat casualties and deaths (Chapter 3).
6. Strive for a duty, career, and personal life environment that increases retention, enhances readiness, and promotes performance (Chapter 4).
7. Invest more in people-centered research to support the introduction of useful new technologies and to increase efficiency (Chapter 5).
8. Develop a more integrated system for managing people in response to advancing technologies, in order to increase efficiency and improve readiness (Chapter 5).

Discussion of Strategic Objectives

Manpower and Personnel

1. *Recruit a higher proportion of people with above-average abilities, including already trained people through lateral entry, and retain high performers for longer periods.*

Personnel selection pays off. During the late 1970s, the Armed Services Vocational Aptitude Battery (ASVAB) was misnormed,² with the result that the test scores of recruits were highly inflated. Because of this error, about 30 percent of recruits actually fell into the lowest acceptable category, rather than the 5 percent being reported at the time. In the aftermath of the misnorming problem, Congress ordered the Services to validate the ASVAB as a selection device by using hands-on tests of performance. Based on analysis of the results of these new tests, an estimated \$3 billion across all of the Department of Defense (DOD) was lost in lower than expected productivity as a result of this inadvertently poor selection. Clearly, continuing vigilance to maintain the validity of the ASVAB is necessary.

The Navy and Marine Corps, like all the Services, take a bifurcated approach to recruiting. Most enlisted recruits are high school graduates, and most officers are college graduates or beyond. This model has served well in the past because most young people fell into one or the other of these two categories. In the future, however, continuation of current recruitment practices may become increasingly problematic because more and more young people are graduating with associate degrees from community colleges and thus fall outside the two categories. Cur-

²Nord, R., and E. Schmitz. 1991. "Estimating Performance and Utility Effects of Alternative Selection and Classification Policies," *The Economic Benefits of Predicting Job Performance*, J. Zeidner and C.D. Johnson, eds., Volume 3, *The Gains of Alternative Policies*, Praeger Publishers, New York.

rently, the Department of the Navy recruits only about 400 of the more than half a million people who graduate with an associate degree every year. Navy and Marine Corps recruiters should consider expanding their presence in this large market of skilled people—a market that is growing while the Navy Department's traditional market for personnel is decreasing. Policies and procedures, such as provisions for lateral entry allowing individuals who possess advanced skills to enlist at advanced pay grades, or to advance rapidly to them, should also be considered for this population.

Classifying people into their correct job and career categories will also be important. One study using Army test data³ found that the average predicted performance of soldiers could be more than doubled if these data were used to match people to jobs and military skill requirements.

Technology, particularly computer-based testing (using items that can be presented only by computer), can provide comprehensive profiles of the interests, values, and abilities of individual recruits and may yield substantial returns in terms of increased retention and personnel readiness and reduced attrition and recruiting costs. These benefits are likely to be large and should be pursued by systematic programs of research and development in both selection and classification.

The current retirement system, which provides 100 percent vesting at 20 years of service but none before, skews the career lengths of a large fraction of the career force toward 20 years. As a result, some personnel stay too long, and others not long enough. A new system is needed that smoothes out retirement incentives over a longer portion of the career. Furthermore, new late-career retention incentives and modification of the mandatory retirement rules will be necessary to encourage top performers to continue serving in the naval forces.

2. Reduce the numbers of sailors required on ships and ashore, and increase their performance by investing in their professional development and personal well-being.

Fiscal restraints will require that future ships be designed to operate with smaller crews, and technology investments will be necessary to effect this change. Reducing ship manning⁴ has the collateral benefit of reducing the shore infrastructure and overhead required to maintain current ship manning levels. "Outsourcing" and turning more work over to civilians will enable the Navy to achieve substantial savings while still getting necessary work done. The re-

³Zeidner, J., and C. Johnson. 1989. *The Economic Benefits of Predicting Job Performance*, IDA Paper P-2241, Institute for Defense Analyses, Alexandria, Va.

⁴The term "manning" is used as a convenient, generic shorthand for assigning personnel, male or female, to organizational and technical tasks within major systems and support bases.

sources saved can be used to better support the remaining force and otherwise modernize Navy operations.

Since World War II the Navy has reduced the manning of warships—by as much as two-thirds in some cases. However, an optimum mix of people and automation must be established to maximize the cost-effectiveness of operating warships. For example, some combat system departments have increased substantially in the past half century because of the addition of sensors, computers, and weapons that did not even exist earlier, whereas some engineering departments have experienced a 30 percent decrease in manning due to the substitution of gas turbine for steam propulsion.

There should be a total-ship initiative to produce the significant manning reductions that are required. The goal should be a greater than 50 percent reduction, not only of ship manning, but also of the total infrastructure that supports the people on board ships. There are vast differences between Navy manning and its commercial counterparts. The Department of the Navy will have to adapt strategies from commercial practices using fewer but more experienced people to yield lower manning costs and higher readiness. Watch standing, damage control, maintenance and repair, and training all must be examined in light of the need to reduce personnel requirements. The Navy will have to reduce the need for human monitoring and assessment of purely mechanical functions, eliminate excessive layers of supervision, and expand the concept of just-in-time manning.

The Navy will have to design ships for inherent resistance to damage, provide more automation for damage control, and provide better tools for repair parties. It will need to design ships for reduced maintenance and increased reliability; instrument for condition-based monitoring using embedded diagnostics; provide vital equipment redundancy; and expand the concept of fly-in maintenance and repair teams, the use of digital maintenance manuals, and the use of just-in-time maintenance capabilities such as electronic performance support systems. Shipboard habitability and technology that increase the quality of life aboard ship will also be important for future ship design. The Navy should also explore the possibility of enhancing human performance through the use of improved human-machine interfaces, possibly including mind-machine communication.

Finally, the Department of the Navy should elevate training to a position of importance equal to that of operations in systems design requirements and development. It should use embedded training and training on demand, provide continuous learning systems, and expand the use of adaptive training and job performance support systems.

Life-cycle costs, not just shipboard and acquisition costs, should be used as the measure of effectiveness in studies of system tradeoff. Senior management must lead the effort to determine the extent to which legacies of culture and tradition are allowed to drive future ship manning.

Education and Training

3. *Emphasize education for officers as an essential part of career development, especially education in science and engineering.*

Although it is commonly recognized both here and abroad that the real strength of the U.S. educational system is at the graduate level, paradoxically there is little indication that Navy leadership prizes U.S. graduate-level education as a necessary component of an officer's educational background. The discipline in graduate study of tackling an original research problem that has no known "right" answer; of learning how to frame and tackle a question; of knowing how to interpret data, how to draw significant conclusions from them, and how to present and demonstrate the validity of the result provides an extraordinarily effective approach to problem solving that is beneficial throughout a career. The nature of the discipline or the particular problem is less important than the process. The Navy does not value sufficiently the problem-solving potential represented in substantive graduate programs in technology, engineering, and science.

The needs of the Department of the Navy are not limited to what graduate education can supply. The rate of technological change substantially increases the need for officers with a strong undergraduate foundation in science, engineering, mathematics, and technology. It also increases the premium on technically capable and technically talented enlisted personnel.

Navy Department needs are now, and will increasingly become, highly advanced scientifically and technologically. The march of information and communication technology, sensing and display techniques, computer system capabilities, material and power options, and other technically sophisticated capabilities has reduced routine shipboard manning requirements and improved warfighting strength. However, these technical capabilities substantially increase the Navy's need for personnel able to analyze and choose among competing technological avenues, critically assess and lead technological development, and continuously formulate new technological visions.

Present Navy needs in science and technology may now be met insufficiently by its officer corps and civilian laboratory personnel. Moreover, the gradient of the quality and quantity of naval force talents in technology, relative to mission needs, is not positive but negative. This trend limits the technical capacity of our naval forces today and increasingly will isolate them from the technological growth and innovation essential to sustained military effectiveness over the next 35 years. Some indications of this trend are the following:

- The Navy no longer encourages or nurtures postgraduate technical education among its officer corps.
- Fewer of the best U.S. high school graduates opt for a Navy career or a college education in fields relevant to Navy technology needs.

- Few of the students who are preparing for a Navy career via higher education specialize in science, mathematics, or engineering.
- Officers who specialize in science, mathematics, or engineering as undergraduates are less frequently provided postgraduate education, are less rapidly promoted, and are more likely to retire early.
- Navy civilian laboratory personnel, once nationwide leaders in science and engineering, are now less prepared to meet important new Navy needs.

To supply the level of human performance required for naval operations in an increasingly technology-intensive environment, the Department of the Navy will have to do the following:

- Increase significantly the proportion of naval force officers who obtain bachelor's degrees in science, mathematics, or engineering;
- Ensure time in the career paths of all officers who are capable of and motivated to invest the considerable effort required for postgraduate study in science and technology, and ensure that they are rewarded in their careers for their added skills and capabilities;
- Restructure the mode of teaching science and technology at the U.S. Naval Academy with the use of personnel on loan from major research institutions and industrial laboratories and/or the establishment of joint programs with research-based academic institutions;
- Reconfigure promotion policies and practices to retain and more fully reward technically skilled officers and enlisted personnel, who will be increasingly needed for predominantly high-technology naval duties;
- Identify the most promising leaders among those technologically educated for special management talent recognition and fast-track movement to leadership positions that can benefit from their expertise; and
- Place priority on ensuring a continuing stream of fresh, young talent employed in naval laboratories. Those who are retained in a longer career path should have regular opportunities to refresh their talents.

4. Invest more in the conversion of conventional forms of training to technology-based, distributed training.

Education and training are key to developing and sustaining the levels of human performance required by 21st-century naval forces. The effectiveness and efficiency of the Navy's education and training programs can be improved substantially through the application of instructional technologies. Investments in these technologies will yield significant returns that can be used to fill gaps that now exist in the delivery of training, to further modernize training, and to increase its efficiency.

The most fundamental promise of technology applied to training appears to

be its ability to tailor pace, sequence, content, presentation style, and even difficulty to the needs of individual learners. Research suggests that the difference between those taught in classroom groups of 30 and those taught individually by an instructor may be as great as 2 standard deviations in terms of achievement. However, individual, one-on-one tutoring is prohibitively expensive. In military training as in civilian education, providing a single instructor for every student is an instructional necessity and an economic impossibility. Technology—substituting the capital of technology for the labor of human instructors—can replace some of the individualized tutoring and its instructional value that are now lost to economic necessity.

Comparisons⁵ of technology-based training with more conventional approaches have found that its use can raise student achievement by 15 percentile points, that it reduces the time to reach given instructional objectives by about 30 percent, that it lowers costs of training for equipment operation and repair by about 40 percent, and that students generally prefer it. It also makes training more accessible. Use of CD-ROM or newer digital videodisk (DVD) technology to provide training aboard ship and at other dispersed locations can overcome residential classroom limitations of both time and place.

A natural application for technology-based training is in specialized skill areas. If 20 percent of Navy and Marine Corps students in specialized training were to use technology-based training that reduced training time by about 20 percent, the annual savings in training costs and student pay and allowances would amount to many millions of dollars. These economic benefits exclude the improvements in readiness that might result if students were able to graduate earlier from training.

Despite these promising indications, the current use of technology-based naval training is minimal. Available records⁶ indicate that of the 3,139 courses presented by the Navy in FY 1997, only 47, about 1.5 percent, used interactive instructional technology. An additional 49 courses were taught using video teletraining to accomplish learning at a distance. Overall, technology-based approaches are unlikely to be found in more than 4 percent of all Navy and Marine Corps training. It is time to increase their use. Investments in these technologies are likely to increase substantially both the effectiveness and the efficiency of training, to yield significant returns that can be used to fill existing gaps in training delivery, and to increase the pace of training modernization. Moreover, technology-based instruction can allow the collection of data on individual and group performance for use by local commanders in determining the composition of small teams.

⁵Fletcher, J.D. 1997. "What Have We Learned About Computer-Based Instruction in Military Training?" *Virtual Reality, Training's Future?*, R.J. Seidel and P.R. Chatelier, eds., Plenum Publishing, New York.

⁶These records are available from the Defense Instructional Technology Information System (DITIS), which is maintained by the Defense Manpower Data Center, Washington, D.C.

Traditionally, budget decisions on the use of technology-based training have tended to focus almost exclusively on the potential for savings within operation and maintenance (O&M) accounts. There are O&M savings to be gained by investments in converting from current training approaches to those that are technology based, but significant additional payoffs can be realized as well, such as the reductions in time needed to train students and the concomitant increase in the time that these individuals are available for duty. One difficulty is that although the investment needed to convert training programs will most probably come from O&M accounts, major savings will appear in personnel accounts, not in O&M.

Outsourcing is a high-priority concern within DOD. Recent studies have found that costs to produce instructional materials and operate networked training simulations may be lowered and fewer instructional personnel may be required when outsourcing is used.^{7,8} Outsourcing cannot be applied universally in Navy and Marine Corps training, but it can produce significant economies in obvious areas such as specialized skill training and the delivery of relevant education and training programs that are already available from community colleges and trade schools.

Medical Care/Combat Medicine

5. Provide for significant advances in the development and application of medical technologies for reducing combat casualties and deaths.

When combat care is required, the need is immediate and occurs under the most stressful of conditions. Combat care is urgently needed in small contingency actions—such as those in Lebanon and Somalia—that are likely to occur in the future and allow little public tolerance for casualties. Combat care is also vitally needed in bigger wars, which may occur periodically. More than 55,000 Americans were killed in Vietnam, and a sample⁹ of Army and Marine Corps casualties showed that more than 50 percent of the wounded who died, did so within 30 minutes. Further, as the current Gulf War medical debate illustrates, new weapons (chemical and biological) may be available to adversary nations for which new combat treatments are required. Combat care—particularly urgent battlefield care—should be given priority in DOD and Navy Department medical investments and in new technology development. Medical career patterns in the

⁷Tighe, C., and S. Kleinman. 1996. *Outsourcing and Competition: Tools to Increase Efficiency*, Center for Naval Analyses, Alexandria, Va.

⁸Metzko, J. 1996. *Government vs. Contractor Training at the U.S. Army Signal Center*, IDA Document D-1942, Institute for Defense Analyses, Alexandria, Va.

⁹Carey, N.B., C.R. Rattleman, and H.Q. Nguyen. 1996. *Information Requirements in Future Medical Operations*, CAB 96-94, Center for Naval Analyses, Alexandria, Va.

Navy should be modified to emphasize the importance of a capability as well as experience in combat medicine.

Many promising technologies under development or on the horizon could help to improve combat and battlefield care. These include new types of protective clothing that provide greater protection against small-arms fire or shrapnel and against chemical and biological threats. A range of new sensors will be available, such as advanced biochemical sensors and personal status monitors, some of which are implanted, that perform as personal black boxes analogous to black boxes in aircraft. Protective clothing may incorporate some of these sensors and automatically administer physiologically protective agents as needed, as well as some forms of emergency care. Gels are being developed that can be applied directly to wounds on the battlefield, can stop bleeding, and can increase the time available to save a person's life. Similarly, artificial white blood cells can be injected on the battlefield to help the body fight against chemical or biological attack. Other valuable technologies are emerging that will stabilize individuals against shock; enable a wounded person to remain inert but alive while waiting for transport to medical facilities; improve information and communications for deciding evacuation priorities; digitize medical records and provide integrated, interoperable medical databases; and so on.

The Department of the Navy should support accelerated R&D programs in combat medicine that integrate protection and monitoring systems; in at-sea medical systems using telemedicine capabilities; and in advanced pharmaceutical products that are effective against new battlefield weapons. The Department of the Navy should also enhance its combat medical capability through the development of a battlefield threat assessment and response system by supporting R&D in biotechnology to improve methods for early detection, identification, and countermeasures to prevent or neutralize the adverse effects of chemicals, toxins, or biological threats; to counter nuclear and directed-energy threats; and to provide the means to reduce the risks posed by environmental hazards. Finally, and most importantly, the Navy should place much more emphasis on the pursuit of combat medicine capability in its medical caregivers and should reward those who specialize in combat medicine more fully in accord with its value to U.S. naval forces and naval operations.

Quality of Life

6. *Strive for a duty, career, and personal life environment that increases retention, enhances readiness, and promotes performance.*

A recent study¹⁰ of the quality of life (QOL) in the Marine Corps demon-

¹⁰Kerce, Elyse W. 1995. *Quality of Life in the U.S. Marine Corps*, TR 95-4, Navy Personnel Research and Development Center, San Diego, Calif.

strated a causal relationship between QOL and behavioral outcomes, including readiness, reenlistment intentions, and performance. These results support what military leaders have long believed—i.e., that QOL investments have an important payoff in desired military outcomes. Additional research is needed to track these investments, the scope of their implementation and use, and their impact on measures of outcome. In many instances, the data required are collected but not made available. Means should be found to place them in databases that can be used to inform decisions about investments in QOL.

The Navy and Marine Corps can ensure an acceptable level of quality of life for members and families and, in turn, contribute to retention, readiness, performance of duty, and overall mission accomplishment, by giving priority to the following five areas:

- *Commitment and community.* Positive perceptions of Navy and Marine Corps life are critical in attracting and retaining qualified personnel, and QOL in duty-related life domains has an impact on morale and performance. The Navy should continue to encourage and develop commitment to the organization and a sense of connection to the military community by demonstrating concern for members and families through a range of QOL services. Innovative programs to build and foster commitment and community among Navy and Marine Corps families, such as the U.S. Marine Corps (USMC) Family Team Building and Community Action Process initiatives, should be encouraged. Privatizing the delivery of QOL benefits and services should be reviewed.

- *Workplace characteristics.* As new technologies reshape the workplace, there is a need to ensure that the cognitive and sensory demands of complex tasks do not exceed normal human capabilities or reasonable levels of stress. The Navy must maintain a watch for unintended consequences of technology in the workplace so as to take optimum advantage of the potential for enrichment and minimize the negative aspect of restructuring. Duty assignment is a critical QOL component, and it requires better matching of individual capabilities and preferences with job demands.

- *Communication.* Separations due to training, operational deployments, and unaccompanied tours of duty are typically considered among the most difficult aspects of military family life.^{11,12,13} The availability of improved communication technologies should be exploited to help deployed personnel deal with

¹¹Cooke, T.W., A.J. Marcus, and A.O. Quester. 1992. *Personnel Tempo of Operations and Navy Enlisted Retention*, CNA Research Memorandum, Center for Naval Analyses, Alexandria, Va., pp. 91-150.

¹²Coolbaugh, K., and A. Rosenthal. 1992. *Family Separations in the Army*, U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, Va.

¹³Segal, M.W., and J.J. Harris. 1993. *What We Know About Army Families*, U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, Va.

one of the major stresses of Navy life and to enhance QOL by providing opportunities to maintain closer contact with families and other loved ones. Leaders must learn how to manage the use of these communication technologies without compromising the security of the mission or the well-being of the Service member.

- *Professional growth.* Because of the skills and skill levels required to protect its education and training investment, the Navy Department will increasingly stress retention and will include a greater percentage of career personnel who are both better trained and older than members of today's force. In general, higher educational levels engender greater expectations, which in turn emphasize the importance of QOL in both duty and personal life domains. The growth of military professionalism must be provided for among both enlisted and officer Navy Department personnel.

- *Research and analyses.* Regular, systematic assessment of QOL should be established and routinized. Available technology and information systems can be used effectively and efficiently to build centralized databases of demographic information that can be combined with other data to answer questions about the utility and cost-effectiveness of QOL programs. The results of these efforts should be applied to allow policy makers to make more informed decisions about tradeoffs among programs based on their utility and their contribution to mission accomplishment. Results of these efforts should also be used to strike a proper balance overall between resources allocated to QOL programs and those allocated to meet other Navy Department needs.

General R&D Objectives

7. Invest more in people-centered research to support the introduction of useful new technologies and to increase efficiency.

A substantial number of new technologies will become available over the next several decades to help improve the way the Navy Department makes use of its human resources. Understanding both the strengths and weaknesses of technologies available for improving performance, facilitating training and education, and improving QOL for service personnel and the cost-effectiveness of different approaches for applying those technologies should be important research objectives. Otherwise, technologies that could enable more effective use of the Navy's human resources may be applied in a piecemeal and less efficient way. Research into the cultural and organizational implications of technological change will also be important because these factors are at least as significant for effecting change as the technology itself. Systematic review of developments in understanding of human cognitive processes, limitations, and workload constraints should be part of this research agenda. Periodic full-system analyses will

be needed to understand the interactions among technologies and the tradeoffs among the various means for developing and maintaining human productivity.

Research in performance enhancement, training and education, and QOL, especially applied research that could help organizations make choices among technologies and facilitate their adoption, appears to be limited. Data on investment in research in this area are hard to come by, but the investment appears to be relatively small. For example, in FY 1996, the Department of the Navy invested only \$29 million in the two congressional budget categories associated with people-centered research relevant to training (education and training, simulators and training devices), when the total amount spent on residential training for individuals, excluding the amounts spent on field and fleet training, was more than \$5 billion. Also in FY 1996, Navy Department spending on all human resource research was about \$86 million from a military work force account of more than \$23 billion. This area might be examined further, with the aim of developing an overall investment plan. The return on a research investment of this type could be substantial.

8. Develop a more integrated system for managing people in response to advancing technologies, in order to increase efficiency and improve readiness.

Many components combine to produce the human resources—the human competence—needed by the Navy and the Marine Corps. Among these are recruitment, selection, classification, assignment, training, and job design (which includes ergonomic design of equipment, as well as use of job aids or performance support systems). All of these components are interdependent. If they are managed as independent stove-piped entities, their interactions will not be accounted for, and improvements sought in one component may be overwhelmed by consequences created elsewhere. For instance, self-paced instruction provided by a training system will be of little value if the personnel system cannot cut orders to meet varying graduation times or to provide rewarding assignments for those who finish early. Alternatively, issues seen as problems in one component may be better resolved by investment in another. For example, issues treated as training problems may be better resolved through adjustments in classification or job design. Studies have found that the Air Force Integrated Maintenance Information System (IMIS), which provides just-in-time advice to maintenance technicians, can reduce training and selection requirements. Implementation of IMIS provides another instance in which one budget category (acquisitions or operations) must pay for an investment whose returns are found in another budget category (personnel). It also illustrates well the need to better understand system-wide, cost-effectiveness tradeoffs among selection, training, and job-aiding.¹⁴

¹⁴Teitlebaum, D., and J. Orlansky. 1996. "Costs and Benefits of the Integrated Maintenance Information System (IMIS)," IDA Paper P-3173, Institute for Defense Analyses, Alexandria, Va.

The full human resource system must be taken into account. Investments in personnel selection, classification, assignment, training, and job design should be balanced and coordinated to optimize returns in readiness and force effectiveness. The key may be to view the provision of mission-ready, competent human performance as the goal, rather than seeking isolated improvements in training, selection, human factors, or other essential but subsidiary components of the system.

Developing and maintaining a system view of human performance or human resources will require both cultural and organizational changes, as well as research and analyses of the system-wide costs and effectiveness of different approaches. Organizationally, there needs to be a Navy Department focal point where all aspects of human resources are routinely considered together as an interacting system. The Navy and Marine Corps should consider creating a personnel "battle lab" whose role would be to develop and assess human-centered technologies for more efficient use of people. This battle lab could also be tasked to manage the changes necessary to transfer promising approaches from research to their intended areas of application. Battle labs have been used in this context by both the Army and the Air Force.

Moreover, personnel research and analyses are needed to assess interactions and tradeoffs and to address gaps in management of Navy readiness. They should include ongoing, high-level review of our understanding of human cognitive processes, limitations, and workload constraints. This review should be used to inform policy decisions about human resource management, design of weapons systems, and operational doctrine. Research and analyses of this sort are not expensive. Currently, the ratio of research money invested in human resource issues relative to the amounts spent on human resources appears to be less than one-half of 1 percent. It may deserve to be increased. The payoff will exceed the required investment.

A FINAL WORD

It should be recognized that human competence is essential to every Navy and Marine Corps operation. Its presence will not guarantee the success of these operations, but its absence will most certainly ensure their failure. The availability of human performance at the highest practicable levels of competence is a matter of first importance to the Department of the Navy. Investments in human resources that are modest compared to other areas will yield substantial returns. They should be treated as significant issues that deserve both priority and high-level attention.

Human Resource Issues for the Navy and Marine Corps

A most difficult aspect of the task facing the Panel on Human Resources involved seeing over the horizon—anticipating developments and requirements that will be present in the year 2035. How might the United States have developed training for World War II before we fought World War I? How might our nation have prepared for the Korean War in, say, 1920?

Revolutionary breakthroughs are rare and, by definition, difficult to foresee. It is possible, however, to extrapolate developments that are evolving from current technology and global trends. The panel sought to determine what might be done now to encourage the evolution of capabilities and practices that will ensure the effective and efficient acquisition and management of human resources needed by the Navy and Marine Corps to meet operational requirements in 2035. The panel specifically tried to identify areas in which relatively small investments are likely to yield substantial returns.

Some aspects of the operational environment likely to exist in 2035 could have a substantial impact on the development and management of human resources and deserve emphasis here. The panel assumed the following:

- Service personnel will be inundated with technology and information.
- Fewer people will be required or available for Navy and Marine Corps missions, but the investment in those people will be greater. Individuals will have more training, autonomy, decision-making responsibility, and military value.
- Many operations will involve joint and/or multinational forces. Service personnel will have to deal successfully with organizational and cultural diversity and to coordinate their operations with both military and civilian organizations.

- Units will be dispersed, but most operations will require rapid task organizing and training for preparation of forces. The Department of the Navy will require the capability to determine quickly and accurately the location and capabilities of units and individuals and their specialized skills and knowledge.
- Responsibilities for missions other than war (i.e., peacekeeping, peace imposition, disaster relief, and counterterrorism) will continue. These missions will require rapid, ad hoc preparations for unusual and unforeseen contingencies.
- Biological and chemical threats will increase.

On the basis of these considerations, the panel arrived at eight strategic objectives. It was the consensus of the panel that these objectives require and deserve the attention of the Chief of Naval Operations (CNO) if our nation's naval forces are to develop and maintain the human resources—the human performance and competence—they will need to meet the challenges of the 21st century. These eight strategic objectives are discussed in the remainder of this report.

RECRUITING PEOPLE OF ABOVE-AVERAGE ABILITY

Recruit a higher proportion of people with above-average abilities, including already trained people through lateral entry, and retain high performers for longer periods.

The quality of the fighting force can be linked directly to the quality of recruits entering the Navy and Marine Corps. The quality of recruits can be measured within a two-by-two matrix based on high school degree and score on the Armed Forces Qualification Test (AFQT). The highest-quality recruits are high school diploma graduates (HSDGs) who score within the upper half of the AFQT. As a group, high school dropouts, including those who go back for a general equivalency diploma (GED), and recruits in the lower mental category perform more poorly on all performance criteria than do HSDGs.

High quality in recruits implies better individual performance and better unit performance. Much research has shown that high-quality recruits are more likely to complete their first term of service, less likely to be demoted or receive nonjudicial punishment, and more likely to be promoted faster and further than others.

Strong evidence of these benefits comes from a misnorming incident of the late 1970s.¹ Test scores on the Armed Services Vocational Aptitude Battery (ASVAB) were misnormed so that recruits received highly inflated scores on the AFQT, the test composite that determines eligibility for service. Because of this

¹Schratz, M.K., and M.J. Ree. 1989. "Enlisted Selection and Classification: Advances in Testing," *Military Personnel Measurement: Testing, Assignment, Evaluation*, M.F. Wiskoff and G.M. Rampton, eds., Praeger Publishers, New York.

error, about 30 percent of the recruits fell into the lowest acceptable category (i.e., Category IV), six times the percentage being reported then. In the aftermath of this problem, Congress ordered the armed services to validate the ASVAB as a selection device using hands-on tests of performance. Analysis of the results of these new tests indicated that the Department of Defense (DOD) lost about \$3 billion in productivity as a result of this inadvertently poor selection of recruits for service. Over the past few years, the attrition gap between the highest-quality recruits and others appears to be growing. This trend suggests the importance of increasing the quality of people as technology increasingly pervades naval operations.

Recent research has shown that the recruit quality of crews in operating units such as surface combatants is positively correlated with higher unit readiness as measured by Status of Resources and Training System (SORTS) scores.² The SORTS reporting system incorporates four areas of unit readiness: personnel, training, materiel, and equipment and supply. Each of these four areas improves as the quality of the crew improves.

SELECTIVE RECRUITING THROUGH MORE LATERAL ENTRIES

The Navy and Marine Corps, like the other Services, take a bifurcated approach to recruiting. Most enlisted recruits are high school graduates, and most officers are college graduates or beyond. This model was fine in the past because most young people fell into one or the other of these two categories. In the future, continuation of current recruiting practices may become increasingly problematic because more and more young people are graduating with associate degrees from community colleges and so fall between the two categories. Today, there is nearly one graduate from a community college for every two high school graduates not going to college. The Navy Department recruits only about 400 yearly of the more than half a million associate degree graduates, however. Navy and Marine Corps recruiters should consider entering this large market of skilled people—a market that is growing while the Navy's traditional personnel market is decreasing. Lateral entry can provide the means by which people with skills that have been developed in the civilian economy can be invited or induced into the Services so that those skills and knowledge can be made directly available to the military. This approach is consistent with the adopt-and-adapt philosophy that emerged in this study as a useful strategy for the Navy and Marine Corps.

Community college graduates offer several advantages. First, on average, they have higher test scores than high school graduates. Second, they have lower attrition rates than high school graduates. Finally, many community college

²Jondrow, J.M., L.J. Junor, J.S. Oi, M.T. Robinson, and M.M. Simons. 1995. *Measuring the Status of Readiness and Personnel Quality*, CAB 95-75, Center for Naval Analyses, Alexandria, Va.

graduates have skills and training that normally must be provided through the Navy's own training investments. By recruiting community college graduates and taking advantage of their skills, it may be possible to avoid some training costs. The Department of the Navy may well be able to take a more proactive role in this activity. It could work with community colleges, perhaps through the American Association of Community Colleges, to suggest curriculum and curricular changes that would produce graduates who are specifically prepared for Navy and Marine Corps careers.

One way in which technology can be employed to extend recruiting onto community college campuses is to expand recruiting efforts on the Internet. In only a few years, employment sites have become quite common on the Internet. Internet sites can be used to post job announcements and to provide general information and advertising. Advertising on the Internet has quickly become as sophisticated as advertising using other media. In any case, the Navy will need to modernize its recruiting procedures and marketing efforts in order to remain competitive.

Recruiting more extensively from the community college market will pose challenges to both the recruiting and the training community. Recruiters may have to provide new incentives such as advanced pay grades, scholarships, and recruiting bonuses. The training system may have to become more flexible to manage people with different incoming skill levels. Review of past Navy Department programs for lateral entry and analysis of lessons learned from them will be needed to recommend policies and procedures for similar programs to be initiated today or in the future.³

KEEPING PEOPLE LONGER

Overall, the Navy's retention pattern falls somewhere between the extremes of the Air Force (on the high side) and the Marine Corps (on the lowest side). The desired retention rate for the first term of Navy service is close to 50 percent. In contrast, the Marine Corps wants to keep only about 20 percent of those completing their first term. The comparable Air Force rate is 60 percent.

Increases in the retention rate have positive benefits for the Navy. First, if the Navy keeps more of its people, it will have to recruit and train fewer. Given the problem of early attrition, the Navy now needs to recruit more than 1.5 recruits to get one sailor to the end of his first term. Easing the attrition problem will also ease recruiting. Second, as discussed below, more experienced personnel are more productive.

Three major factors that historically have affected Navy retention are (1) relative military and civilian pay, (2) the tempo or pace of personnel deployments

³See, for example, Tyson, K.W., and S.A. Horowitz. 1992. *Lateral Entry of Military Personnel*, IDA Paper P-2565, Institute for Defense Analyses, Alexandria, Va.

(PERSTEMPO), and (3) sea-shore rotation. During the 1980s the average wage of young men, the main source of military personnel, fell relative to inflation. After large pay raises in the early 1980s, military pay remained flat relative to inflation. Studies and analyses⁴ have suggested that these trends contributed to the general improvement in force personnel quality.

The Navy uses the following three rules for managing PERSTEMPO:

1. Units cannot be deployed for more than six months at a time;
2. Over a five-year period, a unit cannot be away from home port for more than half the time; and
3. The turnaround time, or time between deployments, must be at least twice as long as the length of the deployment.

These rules have been instituted as a way to manage retention. The fear is that violating them will cause significant numbers of sailors to leave the Navy. At least one study⁵ suggests, however, that expanding deployments beyond six months does not necessarily decrease retention. The study, covering deployments between 1977 and 1988, examined the relationship between PERSTEMPO and retention. Deployments were divided into four categories: short (4 to 5 months), normal (about 6 months), long (about 7 months), and very long (8 or more months). Statistically, the study was unable to distinguish among the retention behavior for sailors on short, normal, and long deployments; it showed little impact from the increased length of deployment. Fleet sailors have suggested one caveat to these findings. Some of the long deployments were associated with challenging and exceptional deployments (crisis responses), which tend to boost morale. The impact of these deployments on the morale of fleet sailors' families remains to be determined.

If the Navy has fewer platforms but faces a steady stream of humanitarian, crisis response, and other missions, it may encounter increasing problems in PERSTEMPO. With changes in technology, the time between maintenance cycles is likely to increase, and units will remain on station longer. PERSTEMPO will increasingly become a driving factor in ship schedules. To alleviate some of the retention pressures associated with higher PERSTEMPO, the Navy may have to investigate ideas such as rotating crews and not ships—a concept similar to use of the Navy's blue-gold crews for ballistic missile submarines. The difference is that crews or portions of crews could be flown out to deployed ships, which

⁴Jondrow, J.M., L.J. Junor, J.S. Oi, M.T. Robinson, and M.M. Simons. 1995. *Measuring the Status of Readiness and Personnel Quality*, CAB 95-75, Center for Naval Analyses, Alexandria, Va.

⁵Cooke, T.W., A.J. Marcus, and A.O. Quester. 1992. *Personnel Tempo of Operations and Navy Enlisted Retention*, CRM 91-150, Center for Naval Analyses, Alexandria, Va., February.

would remain on station. This approach would increase the coverage of a smaller fleet without unduly affecting retention.

Sea-to-shore rotation is another factor that may influence retention. Increases in the amount of sea duty are traditionally associated with lower retention. This fact will be of particular significance in the coming century because of outsourcing. Outsourcing is likely to have a much greater impact on shore billets than on sea billets. The Navy's current plan to outsource 30,000 military billets will increase the average sea-to-shore rotation from about 3.7 years at sea for each 3 years ashore now to about 5.7 years at sea for each 3 years ashore in the next century.

Another form of rotation might be tried. For some occupational areas, careers might be designed with alternating military and civilian billets. An individual might spend 5 years in a military billet followed by 5 years in a civilian billet, followed by 5 years in a military billet, and so forth. The intention would be to increase both retention and competence for billets in some designated career fields. Analyses would be required to determine if this sort of rotation might accomplish these desirable ends.

The CNO should appoint a committee to devise a comprehensive strategy for improving the conditions of sea duty. Such a strategy will need to cross many boundaries within the Navy from acquisition to personnel policies to fleet operations. Engineering reduced manning into ships and reducing the drudgery required to maintain them could be dual goals of the acquisition process. Personnel policies such as increased compensation for voluntary extensions of sea duty could encourage greater retention. Reducing watch-standing requirements and rotating crews on ships without losing operational effectiveness might be best managed by the fleet. By integrating efforts in these three (and possibly other) areas, the Navy could develop a unified and effective plan for increasing retention.

ASSESSING TODAY'S QUALITY

The Navy's recruit quality has improved dramatically since the early 1980s.⁶ For example, in FY 1980 the Navy recruited 75 percent HSDGs and 51 percent in the upper mental groups—personnel classified in Categories I to IIIA on the Armed Forces Qualification Test. By FY 1995, these numbers had improved to 95 percent and 67 percent, respectively. Today, the Navy recruits about 62 percent from the very best group (HSDG and upper mental group) in contrast to only about 38 percent in 1980. Also, the Navy no longer recruits personnel from the lowest acceptable mental group (Category IV) and limits its recruiting among

⁶Jondrow, J.M., L.J. Junor, J.S. Oi, M.T. Robinson, and M.M. Simons. 1995. *Measuring the Status of Readiness and Personnel Quality*, CAB 95-75, Center for Naval Analyses, Alexandria, Va.

Category IIIB personnel to HSDGs. In spite of this excellent record of improvement, the Navy ranks last among the Services in its ability to attract high-quality recruits. The Air Force recruits nearly 90 percent upper-mental-group HSDGs and more than 95 percent HSDGs. The Army and Marine Corps are much closer to the Navy, but in most years they have had a slightly greater proportion of high-quality recruits.

As recruit quality has improved, benefits have been felt throughout the fleet. The Center for Naval Analyses devised an index⁷ to measure the changes in crew quality based on the influence of crew characteristics on SORTS scores. The Personnel Quality Index includes five components: (1) percentage of the crew who were high school degree graduates; (2) percentage of the crew who score in the upper half of the AFQT; (3) average number of years of service; (4) percentage of the crew demoted; and (5) percentage of the crew promoted to E-5 (second-class petty officer) within the first four years of service.

Each of the first three factors is positively correlated with higher SORTS scores. Demotions are much more frequent among junior personnel and also among high school dropouts. As retention falls or recruit quality declines, demotions become more frequent and readiness declines. Finally, in the Navy's vacancy-driven advancement system, rapid (too rapid) promotions are more common during periods of low retention. Monitoring recruiting success and retention levels then provides much of the critical information necessary to monitor the health of the personnel system.

The Personnel Readiness Index is one way to capture in a single metric the cumulative effect of recruiting and retention in the present relative to the past. In order to tie this index to fleet readiness, separate indicators are constructed for specific platform types. Figure 1.1 shows the index of personnel quality for surface combatants over the last 20 years. As the Navy approaches the end of its planned downsizing, the Personnel Quality Index for surface combatants is high. The index is displayed on a scale with a mean of 0 and a standard deviation of 1. At the end of FY 1995, the index stood more than 2 standard deviations above the average level over the entire period and 3 standard deviations above the level during the hollow force of the late 1970s and early 1980s. The index improved steadily throughout the middle and late 1980s as improvements were made in recruiting performance. A greater proportion of recruits came in with school diplomas and in the upper mental groups. As recruit quality improved, discipline problems started to wane and demotions fell. The index started to accelerate upward in the 1990s as a result of the downsizing. Recent data suggest that quality as measured by the Personnel Quality Index is leveling off.

⁷Jondrow, J.M., L.J. Junor, J.S. Oi, M.T. Robinson, and M.M. Simons. 1995. *Measuring the Status of Readiness and Personnel Quality*, CAB 95-75, Center for Naval Analyses, Alexandria, Va.

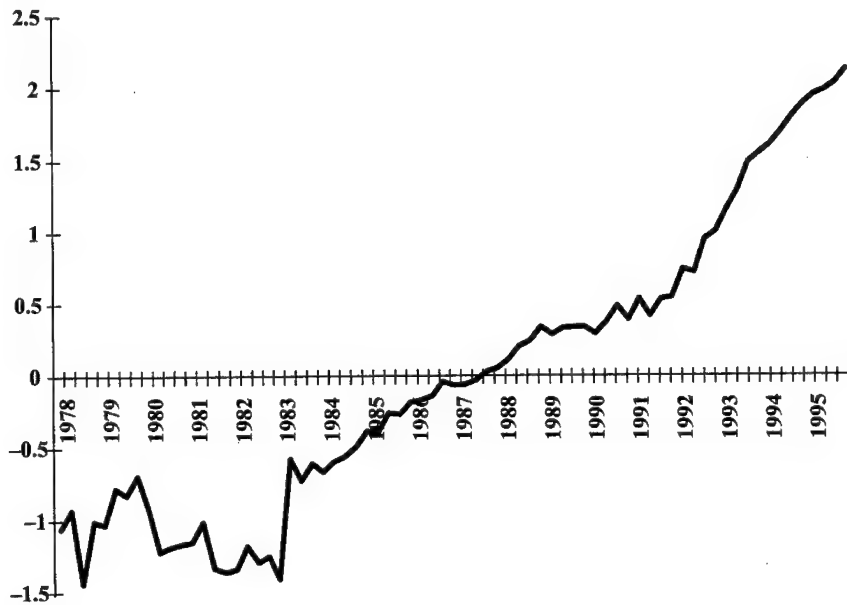


FIGURE 1.1 Personnel Quality Index for surface combatants. SOURCE: Adapted from Junor, L.J., and J.M. Jondrow. 1997. *A Measure of the Quality of Our Forces*, CNA annotated briefing 97-31, Center for Naval Analyses, Alexandria, Va., p. 8.

The Personnel Quality Index rose so rapidly during downsizing partly as a result of the Navy's strategy to avoid involuntary layoffs. As recruiting was curtailed, the average tenure of sailors rose rapidly. Figure 1.2 shows both historical and projected average tenure for the enlisted Navy. In just six years, the average increased from 6.8 years in 1990 to about 8.2 years in 1996. This high level of readiness is not sustainable under the Navy's current program. After a few years, one of the major benefits of the downsizing strategy (i.e., the relatively large career force) will be lost through retirements and will be replaced by relatively large cohorts of recruits. Recent data suggest that quality as measured by the Personnel Quality Index is leveling off. Projections indicate that the average tenure will return to pre-drawdown levels by about FY 2005. The only way to maintain the higher average tenure rates into the future will be for the Navy to increase its retention rates.

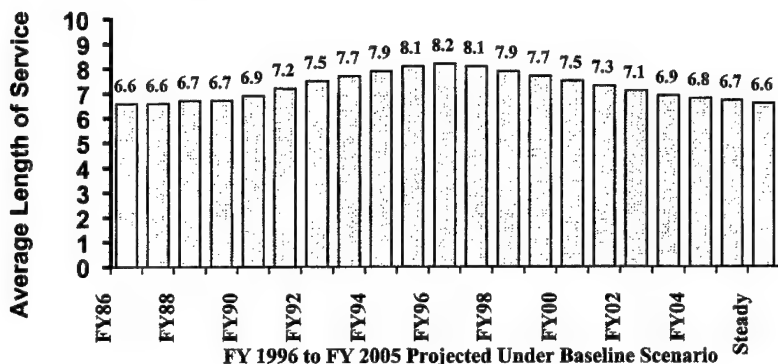


FIGURE 1.2 Seniority trends: average length of service, 1985 to 2005. SOURCE: Griffis, H.S., H.L.W. Golding, and C.S. Moore. 1997. *Costs and Benefits of Aging the Navy's Enlisted Force*, CNA annotated briefing 97-14, Center for Naval Analyses, Alexandria, Va., p. 7.

LOOKING TO THE FUTURE

The changing demographic profile of the United States could pose both a challenge and an opportunity for the Navy. Three demographic factors seem especially worth considering: (1) the rate of growth of the total population, (2) shifts in the age distribution, and (3) shifts in the racial and ethnic composition of the population. The U.S. Census Bureau makes a series of projections of future population growth. This discussion focuses on the middle projection.

The Census Bureau estimates⁸ that by the year 2030, the overall population of the United States will increase by 32 percent compared to 1995, but the youth population (age 15 to 34) will grow by only 15 percent. This youth population reached its low point in 1992 to 1994. It will increase slightly, reaching approximately 90 percent of its 1988 level, after 2000. The reduced supply of 18-year-olds has a significant impact on the Services because industry, academia, and the military must compete for the same quality youth. However, in the absence of a major threat to U.S. security, the Navy's recruiting requirements will stay flat or decline further. With a 15 percent rise in the youth population, recruiting will become easier even though the population is aging.

The racial and ethnic makeup of the population is also shifting. Today, minorities constitute roughly 19 percent of the youth population. By the year 2030 they will increase to about 26 percent. High-level policy within the Depart-

⁸Day, Jennifer C. 1996. *Population Projections of the United States by Age, Sex, Race, and Hispanic Origin: 1995 to 2050*, Current Population Reports, U.S. Bureau of the Census, U.S. Government Printing Office, Washington, D.C., pp. 25-1130.

ment of the Navy is already addressing the issue of diversity. The Secretary of the Navy has established a 12/12/5 goal for officer recruiting—that is, 12 percent of the officer recruits should be African Americans, 12 percent Hispanic, and 5 percent Asian-Pacific Islanders. Considerable senior leadership attention is also being paid to increasing ethnic diversity in high-technology enlisted occupations. With improved training and educational technology, the Navy may be in a better position to help disadvantaged youth overcome shortcomings in the educational system.

Although U.S. demographic trends alone may not pose a problem for the Navy's ability to attract a sufficient number and quality of recruits, economic trends are a different matter. The declining wages of high school graduates have helped all the armed services achieve their recruiting goals over the past 15 years. Youth earnings that rise faster than the Navy's budget would put considerable pressure on recruiting commands and all other aspects of the human resource system. To remain competitive in an all-volunteer force, starting wages in the military would have to rise also. If youth wages increase by only 2 percent per year faster than the Navy's budget each year for 35 years, the Navy will have to double the size of the military personnel-Navy (MPN) account to remain competitive, lose quality in the force, or cut strength by half. Although demographic trends are often cited as a major concern in the future, it may well be that economics—remaining competitive in the youth labor market—will be a greater source of problems for the future Navy.

Interrelationships

In the discussion that follows, the panel focuses on issues that will affect the overall management of the Navy Department's personnel system in the future. All of these factors are a part of an integrated and interactive system. If one part of the system is changed, it will affect many other parts of the system. For example, if technology reduces the requirement for numbers of people but places greater demands on individuals, such changes will affect whom the Navy recruits, how they are assigned, trained, and compensated, how long their careers should last, and how quickly they can advance through the ranks. It is difficult to predict what changes may be required, but it is clear that policy makers will need flexibility in adjusting to changing circumstances. The personnel system of 35 years ago, which was built around a draft of significant numbers of personnel, is no more appropriate for today than today's personnel system will be 35 years into the future.

Job Classification and Assignment

The Department of the Navy may be able to increase the productivity of its people by better matching individual abilities, preferences, skills, and interests to

the demands of the job. Such a classification and assignment system will take more fully into account the differences in levels of abilities across the population and differences among individuals to better allocate human resources to meet Navy needs. The current classification and assignment system appears to contribute little to making effective job matches. An improved system would increase productivity, job and career satisfaction, and retention by better matching people to jobs. There are two problems with the current system. First, the current composites (i.e., combinations of ASVAB subtests) do not statistically differentiate levels of predictions across jobs. Second, minimum composite cutoff scores are so low that nearly every recruit qualifies for all jobs.

The Department of the Navy could take a two-pronged approach to improving initial job assignments. First, current technology could provide test composites that differentiate and predict the demands of different jobs; it would better match people to jobs.⁹ Second, computer technology and optimal control techniques could be used to optimally distribute personnel across jobs and enhance overall productivity. Research suggests that the cost of such changes would be low relative to the benefits. Evidence for the possibility of improvement comes from Army research because the Navy has not done classification research showing productivity gains in dollar terms. Nord and Schmitz¹⁰ evaluated the economic benefits of improving the mean predicted performance and found that even an increase of only 0.1 standard deviation will reduce recruiting and training costs by millions of dollars.

The Compensation System

The current military compensation system uses a single pay and allowance table for all the Services even though they need quite different personnel. Flexibility has been grafted onto the system through different grade structures and myriad special payments such as selective reenlistment bonuses. To recruit better people and increase the average tenure within the Service, some changes in the compensation system will be necessary.

Probably the most important reform is in the retirement pay system. Under the current retirement system, military personnel are fully vested at 20 years of service, but they are not vested before. Civilian employers are required by law¹¹

⁹For a general discussion, see Kyllonen, P.C., 1995, "CAM: A Theoretical Framework for Cognitive Abilities Measurement," *Current Topics in Human Intelligence*, Volume IV, *Theories of Intelligence*, D. Detterman, ed., Ablex Publishing, Norwood, N.J.

¹⁰Nord, R., and E. Schmitz. 1991. "Estimating Performance and Utility Effects of Alternative Selection and Classification Policies," *The Economic Benefits of Predicting Job Performance*, J. Zeidner and C.D. Johnson, eds., Volume 3, *The Gains of Alternative Policies*, Praeger Publishers, New York.

¹¹These regulations are part of the Employee Retirement Income Security Act of 1974, 29 U.S. Code, Sec. 1053.

to provide partial vesting after only five years of service. The military retirement system skews the career lengths of a large fraction of the career force toward 20 years. As a result, some personnel stay too long, and others not long enough. A new system is needed that smoothes out retirement incentives over a longer portion of the career. Furthermore, new late-career retention incentives and modification of the mandatory retirement rules will be needed to encourage the continuation of top performers. Under the current selective reenlistment program, bonuses are available only to personnel with fewer than 14 years of service. The assumption has been that the retirement pay system provides such strong incentives that retention past 14 years will be close to 100 percent. Once the pay system for retirees is modified, late-career retention bonuses will become necessary.

The move toward recruiting more community college graduates may also require changes in thinking about enlistment and reenlistment bonuses. In current practice, money is allocated separately for the two programs. With increased community college recruiting, the Navy may face tradeoffs between recruiting a new community college graduate or reenlisting and training an active duty sailor. To make rational tradeoffs, planners will have to move funding between these two sources of money much more freely.

Another problem with the current compensation system is the fixed relationship between basic pay and allowances for officers and enlisted personnel. Pay raises are applied at a fixed rate for the entire pay table, and the same rate is often applied to allowances also. In 1979 an E-5 at 8 years of service earned \$742 per month, and an O-3 with 8 years of service earned \$1,570 per month.¹² The ratio of officer pay to enlisted pay was then about 2:1. A similar comparison for 1993 military pay produces about the same ratio. The problem with this fixed ratio is that pay practices in the civilian world have changed substantially over the same period. The President's Council of Economic Advisors reports that the ratio of pay for college graduates (i.e., officer-like workers) to pay for high school graduates (i.e., enlisted-like workers) nearly doubled over the same period.¹³ The council's study suggests that pay changes are much more dynamic in the civilian labor force than in the military and that the Navy and other armed services may need greater flexibility to compete with the civilian marketplace. One final compensation issue deals with impending changes in sea-to-shore rotation and possible changes in PERSTEMPO. The Navy needs a pay system that provides incentives to sailors to extend their sea duty voluntarily and to reenlist in the face of high levels of PERSTEMPO.

¹²Office of the Secretary of Defense. 1991. *Military Pay Compensation Papers*, Department of Defense, Washington, D.C.

¹³Council of Economic Advisors. 1996. *Economic Report of the President*, Council of Economic Advisors, Washington, D.C., February, p. 197.

Mandatory Retirement

Since the passage of the Defense Officer Personnel Management Act in the early 1980s, most officers have had to retire at or before 30 years of service.¹⁴ Most senior personnel are in their late 40s or early 50s when they reach mandatory retirement. Such practices are generally illegal in the civilian economy, even though other government institutions also have mandatory retirement at relatively young ages.¹⁵ With expected improvements in health care and fitness over the next 30 years, such a system will become increasingly wasteful of capable people. The Navy should support increases in the length of a military career as another way of increasing retention. Along with provisions for longer military careers and reforms in military retirement, more capable mechanisms will be required to retire workers who are no longer productive.

Reduced Manning

Reduce the numbers of sailors required on ships and ashore, and increase their performance by investing in their professional development and personal well-being.

Fiscal restraints, among other considerations, compel the Navy to build ships that will operate with smaller crews at the same time that naval operational environments require it to increase its capabilities. Fortunately, advances in technology make satisfaction of both of these demands possible, and this will be accomplished if technology investments are made now to ensure that these advances are included in the design of future ship classes. The Navy has achieved significant reductions (of as much as two-thirds) in the manning of warships, at least in some cases. Figure 1.3 shows the decline over time in manning levels for 10,000-ton cruisers and suggests that crew reductions along with capability enhancements are possible and have historical precedents.

These reductions are not uniform across ship operating departments. Manning for some combat systems departments has increased more than 30 percent in the past half century due to the addition of sensors (e.g., large, phased-array radars; large, bow-mounted sonars; satellite communication), computers, and weapons that did not exist earlier, whereas manning for some engineering departments has experienced a 30 percent decrease due to the substitution of gas turbine for steam propulsion.

Further, an optimum mix of people and automation has to be established to optimize the cost-effectiveness of operating warships. Determining this mix

¹⁴See Retirement Age for Officers Act of 1980, 10 U.S. Code, Sec. 1251.

¹⁵Mandatory retirement was made illegal under the Age Discrimination Act of 1979, 29 U.S. Code, Sec. 623.

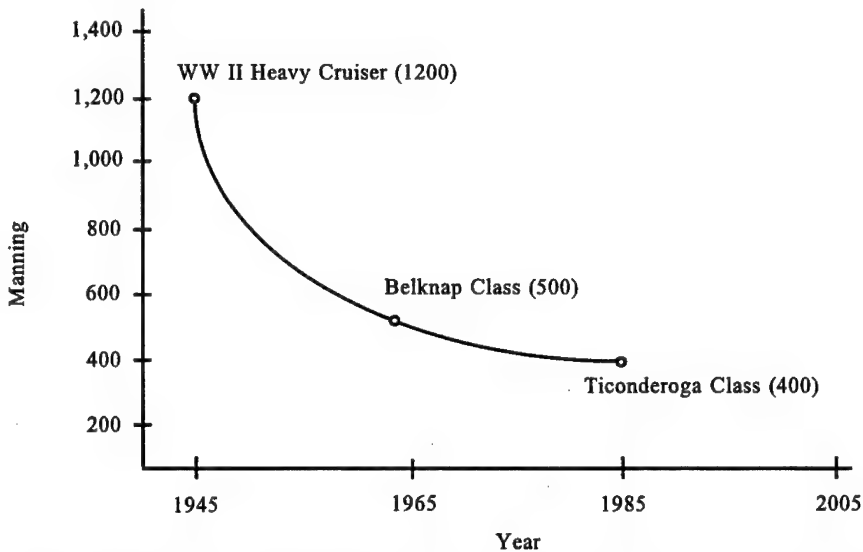


FIGURE 1.3 Manning levels on a 10,000-ton cruiser, 1945 to 1985. SOURCE: Adapted from Glover, CAPT Greg, U.S. Naval Sea Systems Command (PMS 400 FSSP), and Robert Bost, Naval Surface Warfare Command, Carderock Division, "Smart Ship," briefing to Panel on Technology, August 5, 1996.

properly will depend as much on our knowledge of human cognitive and information processing capabilities as on our technological capabilities. Current investments in personnel research and development may deserve review and continuing oversight to ensure that proper levels and priorities have been established to seek these advances.

It should be noted that reducing ship manning has corollary benefits in that it reduces the shore infrastructure and overhead required to maintain current manning levels. Reducing shore infrastructure and undertaking ashore work in a new way—outsourcing and transferring work to civilians—will also enable the Navy to achieve substantial savings while still getting necessary work done. The resources saved can be used to support the remaining force better and otherwise modernize Navy operations.

However, if the Navy pushes hard with important and highly worthwhile efforts such as today's smart ship effort, manning requirements for the 10,000-ton cruiser can be expected to decline from about 400 to about 325 people by 2005. This is neither the radical reduction that many are expecting nor the magnitude of reduction that the panel foresees as being needed. The smart ship represents a systematic effort to reduce the manning required aboard warships. Currently, however, the manning reduction achieved by the smart ship effort is about 44 enlisted billets and 4 officer billets (Box 1.1).

BOX 1.1
Current "Smart Ship" Manning Reductions

Use on-call rather than full watch for advanced intelligence center and Condition III
Use on-call rather than full watch for Repair 8 at Condition III
Use automatic voice recorder for semimonthly log
Reduce radioman manning
Delete closed-circuit television technician
Delete "messengers-of-the-watch" watch station
Utilize forward-lookout rather than port and starboard forward-lookout watch stations
Delete "boatswain mate-of-the-watch" watch station
Reduce electronic technician and data systems technician Navy enlisted code or billet requirements
Reduce yeoman, personnel man, and disbursing clerk workload
Delete Navy counselor billet
Reduce bridge watch team

SOURCE: U.S. Atlantic Fleet, Commander, Naval Surface Force. 1997. Memorandum to Chief of Naval Operations via Commander in Chief, U.S. Atlantic Fleet, re Smart Ship Project Assessment, September 19.

The Navy would benefit from a total-ship initiative to produce the dramatic manning reductions that will soon be required. The goal should be a greater than 50 percent reduction not only on the ship level but also on the total infrastructure that supports the people on board ships. It may be achieved by capitalizing on technological opportunities such as the following:

- Extendible, generic, open architectures for ships systems;
- Advanced human or computer interfaces that include interactive expert systems;
- Automated situation assessment, planning, and execution software;
- High-speed networking; and
- Force multipliers for human-intensive functions.

To do so will require rethinking culture and tradition, technology, and ship design. An effort to answer the following questions may be in order: What cultural changes offer promise for reducing total ship life-cycle-related Navy manning? What technologies offer promise for reducing total ship life-cycle-related Navy manning? What ship design paradigm changes are necessary for reducing ship-related Navy manning?

There are substantial differences between the Navy's manning levels and those of its commercial counterparts for similar functions. A comparison of

TABLE 1.1 Selected Comparisons of Navy and Commercial Ship Manning

U.S. Navy	Commercial
Line handlers (40 to 50, 6 supervisors)	6 to 12
Four to six sections in port duty (65 to 100 per day)	One- to two-man security watch
Large "working parties" to load stores and sweep piers	Vendors load own stores; base commander sweeps piers
Pier sentry provided by ship	Pier belongs to base commander, who provides pier security

SOURCE: Adapted from Glover, CAPT Greg, U.S. Naval Sea Systems Command (PMS 400 FSSP), and Robert Bost, Naval Surface Warfare Center, Carderock Division, "Smart Ship," briefing to Panel on Technology, August 5, 1996.

manning for selected shipboard functions is shown in Table 1.1. It is, of course, not possible to adopt all commercial practices to reduce Navy manning, but systematic review and analysis of these practices would likely yield a valuable set of lessons learned that would more than pay for the effort. The basic difference between the Navy and its commercial counterparts is that Navy officers and personnel supervise routine activities to a much greater degree than in the commercial world. The Navy may have to adapt strategies from commercial practices that rely on the use of fewer but more experienced people, require lower manning costs, and yield greater readiness. The Navy should eliminate the need for human monitoring and assessment of purely mechanical functions, eliminate excessive layers of supervision, and expand the concept of just-in-time manning. Key elements that should be examined in detail include watch standing, damage control, maintenance and repair, and training.

Watch Standing

Examples of initiatives that might be undertaken to reduce manning for watch standing are as follows:

- Eliminate the need for human monitoring and assessment of purely mechanical functions.
 - Eliminate excessive layers of supervision.
 - Expand the concept of just-in-time manning.
 - Eliminate the need for human intervention in system functions and tasks that can be fully automated.
 - Develop and/or adopt multifunction systems.
 - Develop and/or adopt multimedia watch stations.
 - Distribute watch standing among ships.

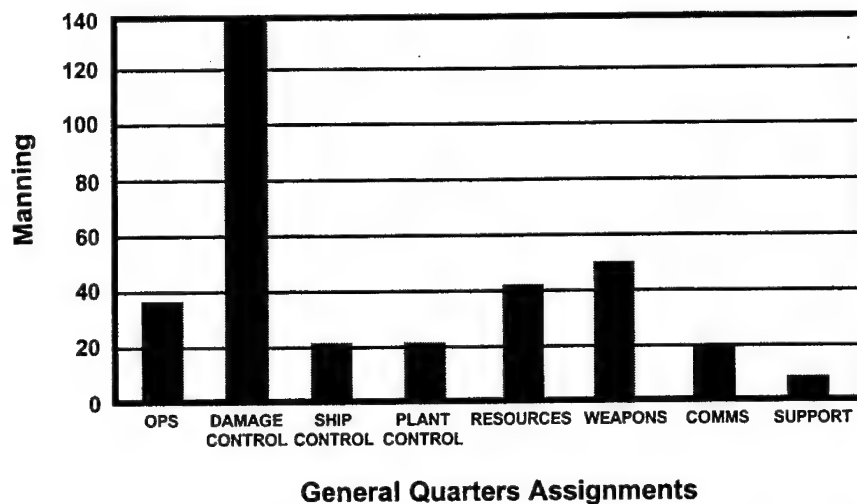


FIGURE 1.4 Relative manning required for damage control in general quarters assignments on a DDG-51, a guided missile destroyer. COMMS, communications; OPS, operations.

Damage Control

Figure 1.4 shows the extent to which damage control functions drive manning in general quarters conditions on one fairly representative class of ships: DDG-51, guided missile destroyers. Initiatives that reduce damage control manning may considerably leverage manning requirements on Navy warships. Examples of initiatives that might be undertaken to reduce manning for damage control are the following:

- Critically examine functional coverage and retain those functions essential to survival—eliminate or defer others.
- Design ships for inherent resistance to damage.
- Provide more automation of damage control functions (e.g., remote controlled fire suppression and extinguishing; robust sensor and alarm systems with video surveillance that are installed in all spaces and that distinguish among and report fire, smoke, heat, and rate and depth of flooding).
- Improve tools to be used by repair parties.

Maintenance and Repair

The Navy should also strive to reduce manning by reducing maintenance and

repair requirements. Initiatives that might be considered in this area are as follows:

- Design for reduced maintenance and increased reliability.
- Instrument for condition-based monitoring using embedded diagnostics.
- Provide vital equipment system redundancy.
- Expand the concept of fly-in maintenance and repair teams.
- Expand the use of digital maintenance, reference, and technical manuals (especially the use of interactive electronic technical manuals).
- Expand the use of condition-based maintenance to replace preventive maintenance where practicable.
- Use advanced materials and coatings to prevent if not eliminate corrosion.

Significant new ship designs may be required to achieve the reductions needed in ship maintenance. Some areas to consider in new designs are low-density arrangement, double hull, size for passive vulnerability, enclaved or zonal manning and systems, blast-tolerant bulkheads and materials, and no-corners housekeeping.

Training

Training is a force multiplier that allows manning reductions through better use of personnel on board. Training and ergonomic design considerations must be elevated to a position of importance equal to that of operations in system design requirements and development. Training initiatives are described at greater length in Chapter 2, but in brief, the following initiatives should be considered as means to reduce manning as well as improve training functions:

- Embed training in systems and provide training on demand—the ship should be empowered to train itself based on its personnel needs, mission assignments, materiel, readiness status, and so on.
- Provide systems that supply continuous learning through continuous, dynamic skill enhancement and automated performance assessment.
- Provide adaptive training that tailors itself to the needs of individuals.
- Expand the use of performance aids such as electronic manuals, automated advisors based on expert systems, and electronic performance support systems.

Mind-Machine Communication

The interface between humans and machines could be dramatically improved through the use of interfaces that read human brain activity and then produce a

desired response. Recent progress in this area suggests that this capability could well be available by 2035. It could have far-reaching implications for control of complex systems such as aircraft or teleoperated vehicles such as small submarines or even smaller devices transporting microsensors in the human body. Mind-machine communication of this sort is of direct interest to the naval forces. It will leverage human performance potential, act as a force multiplier, and permit manning reductions. It should be pursued as a research priority.

Retention

Retention of personnel is another force multiplier and a way to make better use of existing human resources. As new warships are designed and built, the Navy should continue to focus on shipboard habitability and use technology to increase the quality of life at sea. Many research studies and analyses¹⁶ have suggested that, more than any other factor, satisfaction on the job is key to retention. Duty in the naval forces may be arduous and even dangerous, but these conditions should be borne only when necessary. The perception that discomfort and danger have been minimized by the organization to the fullest extent practicable will increase the retention of skilled and experienced individuals.

In conclusion, life-cycle costs, not just those limited to shipboard and not just acquisition costs, should be used as the measure of effectiveness in system tradeoff studies. Senior management must lead the effort to determine the extent to which legacies of culture and tradition are allowed to drive future ship manning.

Competition and Outsourcing

More sailors and most Navy civilians have jobs in naval shore activities. These activities account for a significant portion of the Navy's budget. Shore activities have been closely studied by the Center for Naval Analyses,^{17,18,19} the Defense Science Board,²⁰ and others. As a result, recommendations have been made to significantly change the way the Navy manages its shore activities.

¹⁶Segal, M.W., and J.J. Harris. 1993. *What We Know About Army Families*, U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, Va.

¹⁷Marcus, A.J. 1993. *Analysis of the Navy's Commercial Activities Program*, VRM 92-226.10, Center for Naval Analyses, Alexandria, Va.

¹⁸Tighe, C.E., J.M. Jondrow, S.D. Kleinman, M. Koopman, and C. Moore. 1996. *Outsourcing Opportunities for the Navy*, CRM 95-224, Center for Naval Analyses, Alexandria, Va.

¹⁹Tighe, C.E., S.D. Kleinman, J.M. Jondrow, and R.D. Trunkey. 1996. *Outsourcing and Competition: Lessons Learned from DOD Commercial Activities Programs* (occasional paper), Center for Naval Analyses, Alexandria, Va.

²⁰Defense Science Board Task Force. 1996. *Outsourcing and Privatization*, Office of the Under Secretary of Defense for Acquisition and Technology, Department of Defense, Washington, D.C.

These studies suggest that their recommendations will achieve reductions in operating costs measured in billions of dollars.

Competition is the key to reducing costs. When the Navy opens up an activity in the shore infrastructure to competition, it results in savings of people and money. Studies have shown that across DOD, competition has generated savings averaging 30 percent.²¹ This result holds even when government entities win the competition. The Navy currently is planning to reduce 30,000 billets through competition over the next 10 years. This number represents only about 20 percent of the shore infrastructure. Over the next 30 years it would seem possible to double these savings.

²¹Marcus, A.J. 1993. *Analysis of the Navy's Commercial Activities Program*, VRM 92-226.10, Center for Naval Analyses, Alexandria, Va.

Education and Training

NATIONAL ISSUES

Emphasize education for officers as an essential part of career development, especially education in science and engineering.

The educational system of the United States, if it indeed can be called a system, has a number of strengths, but also some well-recognized weaknesses. Among its strengths is its broad-based attempt to educate all of its citizenry, not just an elite few. It is widely recognized, however, that the typical schooling received in the K-12 age groups does not compete well with the educational systems of our industrialized competitors. International mathematics and science studies describe this problem in detail.¹ On the other hand, the U.S. school system has been able to retain a degree of freedom, individuality, creativity, and spark that these same competitor nations might well wish to emulate. At the college level, U.S. institutions start with incoming students who are often at a serious disadvantage compared to students enrolling from abroad, but our colleges are generally regarded as being competitive in the value added to this part of a student's education. At the graduate level, the United States is widely perceived to excel. Graduate education in the United States has become a mecca for foreign students who want to advance beyond what their own country pro-

¹See, for example, Third International Mathematics and Science Study, 1997, *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study*, Boston College, Boston, Mass.

vides academically. The *Chronicle of Higher Education* has reported that a large proportion of the students in engineering and science graduate fields come from abroad. The large number of foreign graduate students attests to the premium placed on U.S. graduate education.

Although the U.S. educational system apparently produces an adequate number of degree recipients in science and technology, the courses of study available are in many ways poorly matched with Navy needs. There has been a tendency for both the faculty and the students to aim for more prestigious courses of study, those concerned with the exotic and the theoretical at the expense of more practical applied sciences needed for naval operations. Many applied science programs have attenuated or have disappeared from academic science departments, in some cases reappearing in engineering departments, while many engineering departments have eschewed applications-oriented studies for science-based education. The fraction of college students enrolled in calculus-based elementary physics has declined over the last 50 years, yet the military's need for individuals with expertise in such a discipline has expanded over this period, not declined.

In many U.S. graduate departments of science and technology, a majority of the students today are foreign nationals and thus do not qualify for either civilian or uniformed employment by the naval forces. Foreign national students who remain in this country and achieve citizenship constitute a substantial fraction (perhaps half) of the total. They represent substantial gains for the United States, but the Navy can attract them, if at all, only in mid or late career.

It is a paradox that although the real strength of the U.S. educational system is at the graduate level, there is little indication that the Navy leadership prizes such education as a necessary component of an officer's background. The discipline in graduate study of tackling an original research problem that has no known right answer; of learning how to frame a question and how to approach it; of knowing how to interpret data, how to draw significant conclusions from them, and how to present and sell the validity of the result provides an extraordinarily effective approach to problem solving that is beneficial throughout a career. The nature of the discipline or the particular problem is less important than the process. The Navy may not value sufficiently the problem-solving potential represented in substantive graduate programs in technology, engineering, and science.

Education takes time in the career path of the officer: time to think, collect and analyze data, organize, and communicate. This time cannot be abridged too severely without losing the effectiveness of the process. Although some officers are engaged in this way of learning, others by choice are serving in the fleet without making the commitment to further learning. The latter tend to be favored by fast-tracking in the Navy's promotion process because they are more visible, making personal contact with active Navy officer superiors who then may tend to advocate their subsequent advancement. Viewed in this light, the extended time spent in serious graduate study, even in fields of critical interest to the Navy, frequently inhibits promotion and advancement compared to those who do not

pursue these paths. The Navy is depriving its future readiness and capability of the use of such technologically astute individuals in larger numbers in its upper leadership.

NAVAL FORCE ISSUES

Navy needs are already highly advanced scientifically and technologically, and the importance of technical literacy among naval personnel will only increase in the future. The march of information and communication technology, sensing and display techniques, computer system capabilities, material and power options, and so forth has reduced shipboard manning requirements for routine duties and has improved warfighting strength. These technical capabilities substantially increase the Navy's need for personnel who can comprehend the potential for warfighting that the new technologies bring, who understand both the opportunities and the limitations they present, who are able to choose among competing technological avenues, who can critically assess and lead technological development, and who can formulate practicable new technological visions.

It is perfectly true that the Navy can and does operate without more of these individuals, and in that sense, it does not need more of them. Nevertheless, technically literate personnel, who are able to recognize which of the new civilian technologies will make a difference in future warfighting capabilities and readiness, could enable the Navy and Marine Corps to field more effective fighting units. In that sense, the Navy needs more than it has, and perhaps all it can get. The current requirements-based personnel system does not necessarily recognize the long-term career enhancement produced by graduate education but rather defines graduate educational requirements in terms of assignments. This approach may result in suboptimization of officer potential, which would be damaging to the long-term readiness of the Navy as a whole.

Moreover, the present trend with regard to technical literacy among Navy Department personnel, relative to need, is not positive but negative and thus sounds the alarm for the desired impact of technology on the Navy in the next 35 years. The following are some indications of this trend:

- Through the mid-1960s, but not much beyond that, the Navy encouraged and nurtured postgraduate technical education among its officer corps; now the Navy's encouragement is weaker, and its nurturing through career growth is largely absent.
- Fewer of the best U.S. high school graduates opt for a Navy career or a college education in fields relevant to Navy technology needs.
- Few of the students who are preparing for a Navy career via higher education specialize in science, mathematics, or engineering.
- Officers who specialize in science, mathematics, or engineering as under-

graduates are less frequently provided postgraduate education, are less rapidly promoted, and are more likely to retire early.

- Navy civilian laboratory personnel, once nationwide leaders in science and engineering, are now less prepared to meet important new Navy needs. Downsizing has inhibited the renewal and innovation that come from the ability to hire a stream of intelligent, highly motivated young people from whom future laboratory leaders can be selected.

To meet the human performance needs of naval operations in an increasingly technology-intensive environment, the Department of the Navy will have to do the following:

- Increase significantly the proportion of naval force officers who obtain bachelor's degrees in science, mathematics, or engineering.
- Ensure time in the career paths of all officers who are capable of and motivated to invest the considerable effort required for postgraduate study in science and technology, and ensure that they are rewarded in their careers for their added skills and capabilities.
- Restructure the mode of teaching science and technology at the U.S. Naval Academy with the use of personnel on loan from major research institutions and industrial laboratories and/or the establishment of joint programs with research-based academic institutions.
- Reconfigure promotion policies and practices to retain and more fully reward technically skilled officers and enlisted personnel, who will be increasingly needed for predominantly high-technology naval duties.
- Identify the most promising leaders among those technologically educated for special management talent recognition and fast-track movement to leadership positions that can benefit from their expertise.
- Place priority on ensuring a continuing stream of fresh, young talent employed in naval laboratories. Those who are retained in a longer career path should have regular opportunities to refresh their talents.

Graduate education provides career-long enhancement of the abilities of an officer, not just a technical specialty skill. Development of problem-solving skills is applicable to all kinds of problems that face the individual in unexpected situations. It is self-evident that there is little time for such education in wartime. The time to devote resources to obtaining graduate education is when the nation is at peace. It should then be a high priority whose payoff is enhanced performance in times of war as well as in time of peace. Graduate education is a generator of future readiness with a high rate of return.

Several steps can be taken to help increase the Navy's commitment to graduate education; they are as follows:

- Make investment in education a priority in officer development, and separate the educational investment category from the individual's account so that graduate students are not thrown into the same personnel categories as prisoners and the medically unfit. Increase the billet assignment to the investment portion of the individual's account for graduate education, deriving those new billets from a portion of the personnel savings recovered from reduced manning and increased outsourcing.
- Revamp the subspecialty system as the basis for a requirement for education. This requirement now limits the Navy's access to graduate-educated personnel, rather than maximizing it.
- Strengthen the precepts to officer promotion boards to pay full attention to the potential of career-enhancing skills provided by graduate education.

These are literally cost-free changes that have the potential to significantly improve the technological capabilities of the future Navy officer corps.

MILITARY TRAINING

Invest more in the conversion of conventional forms of training to technology-based, distributed training.

Training is a means to an end—successful performance of military missions. Training is widely acknowledged to be an essential component in preparing for military operations. There is, therefore, great interest in seeing that military training is performed effectively and efficiently and that training resources are expended wisely. Technology has contributed substantially to the complexity of modern warfare and to U.S. success in war. Technology also provides the means to increase the effectiveness and efficiency of preparing for naval operations. Success in modernizing Navy and Marine Corps capabilities and operations will be of less value if it is not accompanied by success in modernizing the conduct of training as well.

Military training can be described in terms of who is being trained (individuals or groups) and where the training takes place (in residence or in units). Training in residence refers to training presented in formally convened schools under the domain of specifically designated training commands. Training in units takes place in operational or duty assignments. Training of individuals may be contrasted with training of crews, teams, and units. Clearly, the performance of groups depends on the skills of the individuals who make up the groups. The distinction between individual skills and group skills is imperfectly understood, but the focus in individual training is on the performance of individuals, and the focus in group or collective training is on the performance of crews, teams, and units as a whole.

Training of individuals that takes place in residential, schoolhouse settings is

annually reported to Congress in the Military Manpower Training Report (MMTR).² The MMTR describes how the trained manpower projected by another annual report, the Manpower Requirements Report, will be provided in coming fiscal years. The MMTR for FY 1997 estimates that the training load (the number of man-years students are expected to be in training), where

$$\text{Training Load} = \frac{(\text{Entrants} + \text{Graduates})}{2} \times \text{Course Length},$$

will be about 144,632 man-years (or student-years)—officers and enlisted—for active duty personnel and 30,217 man-years for the reserve components—a total training load of 174,849 man-years across DOD. This training will require about 115,000 military and civilian personnel to provide instruction, administration, and supervision, and it will cost about \$13.7 billion.

As shown in Table 2.1, the number of Navy personnel—officer and enlisted, reserve and active—entering formally convened military schools in FY 1997 is expected to be about 586,200, with a training load of 41,600. Comparable numbers for the Marine Corps are 156,200 school entrants, with a training load of 22,500. The FY 1997 costs for this training, as shown in Table 2.2, will total about \$3,866 million for the Navy and \$1,433 million for the Marine Corps, summing to \$5,299 million for the Navy Department.

The MMTR estimates are focused on residential training for individuals and do not reflect all training costs. They include formal course instruction conducted by organizations whose primary mission is training, but they exclude training conducted by operational units, on-job training, factory training for new systems, most team and unit training, and most fleet and field exercises. Although the magnitude of resources allocated to these latter activities is not regularly reported and is difficult to determine, it would probably increase the \$5.3 billion cost estimated for Navy Department training by a factor of two or three.

TRAINING CHALLENGES

Many commentators have discussed current trends that increase the challenges to the successful conduct of military training. Among the points raised by these discussions are the following:

- Workplaces in all sectors have become increasingly infused with technology, requiring workers to become increasingly technology literate. The com-

²Office of the Deputy Under Secretary of Defense for Readiness. 1996. *Military Manpower Training Report: FY 1997*, Department of Defense, Washington, D.C.

TABLE 2.1 Total Student Input and Training Loads Planned for Active and Reserve Component Officer and Enlisted Individual Training in FY 1997

Training Categories	Input (thousands)				Total	Load (thousands)				Total
	Army	Navy	Marine Corps	Air Force		Army	Navy	Marine Corps	Air Force	
Recruit	91.4	55.7	41.6	33.5	222.2	13.9	9.5	7.8	3.7	34.9
Officer acquisition	7.9	3.1	0.9	2.0	13.9	6.0	5.5	0.9	6.3	18.7
Specialized skill	279.7	517.1	103.2	117.1	1,017.1	42.9	23.1	11.6	16.7	94.3
Flight	4.8	3.2	0.4	5.0	13.4	0.9	1.3	0.5	1.8	4.5
Professional development	5.3	7.1	10.1	42.0	64.5	3.7	2.2	1.7	4.8	12.4
One-station unit	41.5	0.0	0.0	0.0	41.5	10.1	0.0	0.0	0.0	10.1
Total	430.6	586.2	156.2	199.6	1,372.6	77.5	41.6	22.5	33.3	174.9

SOURCE: Compiled from data in *Military Manpower Training Report: FY 1997*, 1996, Office of the Deputy Under Secretary of Defense for Readiness, Department of Defense, Washington, D.C., July.

TABLE 2.2 Funding Planned for Active and Reserve Component Officer and Enlisted Individual Training in FY 1997 (million dollars)

Training Categories	Army	Navy	Marine Corps	Air Force	DOD Total
Recruit	\$ 307	\$ 282	\$ 419	\$ 147	\$ 1,155
Officer acquisition	146	210	11	174	541
Specialized skill	1,560	1,497	601	784	4,442
Flight	390	990	0	584	1,964
Professional development	312	216	72	298	898
Army one-station unit	247	0	0	0	247
Direct training support	338	114	64	60	576
Base training support	1,226	499	188	720	2,633
Training management headquarters	46	21	0	71	138
Reserve pay and allowances	703	37	78	265	1,083
Total	\$5,275	\$3,866	\$1,433	\$3,103	\$13,677

SOURCE: Adapted from *Military Manpower Training Report: FY 1997*, 1996, Office of the Deputy Under Secretary of Defense for Readiness, Department of Defense, Washington, D.C., July.

plexity of military operations has continued to increase along with the human performance needed to operate, maintain, and deploy the technology—the materiel, devices, and equipment they employed. It could be argued that technology will decrease the complexity of human performance required by operations in the military and elsewhere, but this has not happened. The demand for people trained to hold jobs that are classified as technical or highly technical continues to increase in the Navy and Marine Corps.

- The quantity and variety of military systems along with the pace of their introduction have substantially increased the demands on military training to provide the people needed to operate and maintain these systems. At the end of World War I, the U.S. military fielded about 500 materiel systems. At the end of World War II, this number had increased to 2,000. Currently, about 4,000 systems are fielded or in planning.

- The technological complexity of military systems is increasing. In 1939, the volume of technical documentation required for the J-F Goose Catalina Flying Boat filled 525 pages. In 1962, the volume required by the A-6A Intruder filled approximately 150,000 pages. In 1975, the volume required for the F-14 Tomcat filled approximately 380,000 pages. Documentation required by the B-1 bomber has been estimated to be 1,000,000 pages of information. This upward trend will no doubt continue.

- Costs to conduct training in the fleet and the field have risen in absolute terms and in terms relative to other DOD expenses. Worldwide land, sea, and air space available for military exercises continues to be reduced as civilian requirements for space increase. Fuel and ammunition for new weapons have been

major contributors to increased military training costs. In addition, the ranges needed to exercise the long reach of the newest systems are scarce, environmentally controversial, and increasingly expensive to establish and maintain.

- Reserve component training poses particularly difficult challenges. The reserve components have a limited time—39 days per year—to train. Reserve units are widely dispersed, not fully equipped, and are supported by only small numbers of qualified supervisors and trainers. Many reserve component trainers for these units are noncommissioned officers who have primary assignments elsewhere and give training short shrift. Yet with a downsized military, we are likely to rely increasingly on reserve component readiness.

It is unlikely that conventional approaches using platform lectures, paper-based workbook exercises, and laboratory experience with actual, scarce, and expensive equipment will meet the demands for the training efficiency and effectiveness required for the coming century. Although technology introduces these problems, it may contain the seeds for their solution. Increasingly, trainers in both military and civilian settings are turning to technology as a source of improved training effectiveness and efficiency.

TECHNOLOGY EFFECTIVENESS

It may be said, with some help from the dictionary, that the word “technology” refers to the application of any effective procedure to solve a specific, practical problem. Popularly, the meaning of technology has become increasingly associated with computers and computer-controlled applications, and this is the sense in which it is commonly used in education and training. Applications of computers and/or computer-controlled capabilities to military training have been around for more than 35 years. After this period of time, it is fair to ask if they have improved either the efficiency or the effectiveness of training.

The most fundamental promise of technology applied to training appears to be its ability to tailor pace, sequence, content, presentation style, and even difficulty to the needs of individual learners. Research suggests that the difference between those taught in classroom groups of 30 and those taught one-on-one by an individual instructor providing individualized instruction may be as great as 2 standard deviations in achievement.³ However, individual, one-on-one tutoring is prohibitively expensive. In military training as in civilian education, the provision of a single instructor for every student is an instructional necessity and an economic impossibility. Technology—substituting the capital of technology for the labor of human instructors—can replace some of the individualized tutoring and its instructional value that are now lost to economic necessity.

³Bloom, B.S. 1984. “The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-one Tutoring,” *Educational Researcher*, 13:4-16.

The primary benefit of instruction tailored to individual needs may be efficiency—students spend less time repeating material they already know and more time concentrating on what they do not know. They should learn more quickly, and this, in fact, is a principal finding of assessments of technology applied in education and training that serves to emphasize the economic and readiness benefits of individualizing instruction.

This finding and others are summarized below. First, however, it may be noted that no single evaluation, no matter how carefully done, is conclusive. The results of many evaluation studies must usually be collected to draw a cumulative picture of what has been learned. In the current state of the art, such collection is accomplished using meta-analysis, which employs a measure called effect size. Effect size is simply a standardized measure defined as the difference between the means of two groups divided by the estimated standard deviation of the population from which they are drawn. In this summary, they are calculated so that the larger the effect size, the greater is the instructional impact of technology.

The main drawback in using effect sizes is that they are, basically, a measure of standard deviations and are not especially meaningful to those who are not statisticians. For this reason, the effect sizes reported here are accompanied by rough translations to percentiles based on the notion that an effect size of, say, 0.50 (half a standard deviation) is roughly equivalent to raising the performance of students in the 50th percentile to that of students at the 69th percentile.

Some findings follow.

Technology Can Be Used to Teach

A number of studies have compared applying technology in education and training to simply doing nothing. The issue here is not to determine whether these applications are a good way to teach or if they teach the right things, but simply to see if they teach anything. The results suggest that they do. For instance, some studies⁴ have compared applications of interactive videodisk instruction (IVI) to placebo treatments in which no instructional material was presented. The average effect size for these studies was 1.38, suggesting an average improvement in student achievement due to the presence of this technology from 50th to 92nd percentile performance.

Additional evidence comes from early studies⁵ tracing student progress, or trajectories, through instructional material. These studies found that based solely on the amount of time students spent in computer-based instruction, the improvement of each student on a standardized test of total mathematics achievement

⁴Fletcher, J.D. 1990. *The Effectiveness of Interactive Videodisk Instruction in Defense Training and Education*, IDA Paper P-2372, Institute for Defense Analyses, Alexandria, Va.

⁵Suppes, P., J.D. Fletcher, and M. Zanotti. 1976. "Models of Individual Trajectories in Computer-Assisted Instruction," *Journal of Educational Psychology*, 68:117-127.

TABLE 2.3 Some Effect Sizes for Computer-based Instruction

Where	Effect Size	Number of Studies	Improvement from 50th Percentile Performance to:
Elementary school	0.47	28	68th percentile
Secondary school	0.42	42	66th percentile
Higher education	0.26	101	60th percentile
Adult education	0.42	24	66th percentile
Military training	0.40	38	66th percentile
Overall	0.39	233	65th percentile

SOURCE: Fletcher, J.D. 1996. "Does This Stuff Work? Some Findings from Applications of Technology to Education and Training," *Teacher Education and the Use of Technology Based Learning Systems*, Society for Applied Learning Technology, Warrenton, Va.

could be predicted to the nearest tenth of a grade placement, within 99 percent confidence limits. If time spent in the computer curriculum had no effect, no predictions would have been possible. In these studies, the precision of the predictions is as notable as the fact that they could be made, and validated, at all.

Technology Improves Instructional Effectiveness

The conclusion that technology improves instructional effectiveness concerns the more common issue of determining whether or not the application of technology allows us to do any better than we can do without it. A typical study that addresses this issue compares an approach using technology, such as computer-based instruction or interactive multimedia instruction, with what might be termed conventional instruction, which uses platform lectures, text-based materials perhaps including programmed text, and/or laboratory hands-on experience with real equipment.

There have been many studies of this sort. Some results for computer-based instruction (CBI) are shown in Table 2.3. Their effect sizes range from 0.26 to 0.47 and average 0.39, which suggests an average improvement from 50th to 65th percentile achievement. A recent review⁶ of 12 meta-analyses involving at least 250 different evaluations of CBI reported an overall average effect size of 0.35, suggesting an increase from 50th to 64th percentile performance after introduction of CBI.

The results shown in Table 2.4 for IVI, which includes the functionalities generally used to describe interactive multimedia instruction, are slightly higher

⁶Kulik, J.A. 1994. "Meta-Analytic Studies of Findings on Computer-Based Instruction," *Technology Assessment in Education and Training*, E.L. Baker and H.F. O'Neil, eds., Lawrence Erlbaum Associates, Hillsdale, N.J.

TABLE 2.4 Some Effect Sizes for Interactive Videodisk Instruction

Where	Effect Size	Number of Studies	Improvement from 50th Percentile Performance to:
Military training	0.39	24	65th percentile
Industrial training	0.51	9	70th percentile
Higher education	0.69	14	75th percentile
Overall	0.50	47	69th percentile

SOURCE: Fletcher, J.D. 1990. *The Effectiveness of Interactive Videodisc Instruction in Defense Training and Education*, IDA Paper P-2372, Institute for Defense Analyses, Alexandria, Va., p. III-10.

than those for computer-based instruction without multimedia capabilities, averaging 0.50 for 47 evaluation studies and suggesting an overall increase in student achievement from 50th to 69th percentile performance. The effect size of 0.69 for interactive videodisk (or multimedia) instruction in higher education is impressive, in that it suggests an improvement from 50th to 75th percentile performance.

Generally, then, these studies present evidence favorable to the use of technology in instruction, suggesting that the introduction of technology improves its effectiveness. There is also much to be said about its military value. Interactive multisensor analysis training (IMAT)⁷ provides an example of technology-based training that has been adopted by all antisubmarine warfare (ASW) communities and has been designated as a congressional special interest program.

IMAT is a product of Navy personnel R&D, developed jointly by the Navy Personnel Research and Development Center and the Naval Surface Warfare Center. It provides sensor employment and tactical training (e.g., environmental analysis, sensor selection and placement, search rate and threat detection, multisensor crew coordination, multisensor information integration) that compensate for the current lack of opportunities to develop and sustain these skills in formal training or on the job. IMAT integrates models of physical phenomena with innovative visualization techniques to demonstrate the relationships among threats, the environment, and ASW systems. It combines new analytic and curriculum design technologies such as cognitive modeling, situational learning, and elaborated explanations with advanced computer-based graphics and programming to promote rapid acquisition of the visualization capabilities needed to

⁷Wetzel-Smith, S.K., J.A. Ellis, A.M. Reynolds, and W.H. Wulfeck. 1995. *The Interactive Multisensor Analysis Training (IMAT) System: An Evaluation in Operator and Tactician Training*, NPRDC Technical Report TR-96-3, Naval Personnel Research and Development Center, San Diego, Calif.

understand the structural and spatial interrelationships that exist among sensors, platforms, and submarine systems.

IMAT⁸ is used in the basic training (A) schools for aviation antisubmarine warfare (AW) operator, sonar technician-systems (STS), and sonar technician-guns (STG), and in submarine officer basic and advanced courses, the surface warfare officer's school, sea-based weapons and advanced tactics school, and (currently) eight other naval training schools. Some findings regarding its effectiveness are as follows:

- IMAT students in STG A and AW A school scored significantly higher on all performance measures (facts, comprehension, and tactical problem solving) than did students in conventional instruction. The overall effect size was 1.26 (from 50th to 90th percentile performance) for IMAT-based STG training and 2.01 (50th to 98th percentile performance) for IMAT-based AW training. Similar results, which are not yet available, are expected for STS training.
- IMAT graduates scored significantly higher than fleet personnel with 3 to 10 years' experience on an oceanography knowledge and skills test.
- Apprentice AW operators who were trained using IMAT scored higher than journeyman fleet personnel on acoustic problem solving.
- IMAT-trained pilots and tacticians scored significantly higher than performance qualification standard (PQS)-qualified fleet personnel on all ASW performance measures.
- IMAT produced a four- to six-year equivalent experience gain in search planning for non-PQS qualified officers.
- IMAT-trained submarine crews significantly improved their tactical employment skills.
- A 10-decibel (dB) tactical gain was achieved in at-sea trials; i.e., objects had the same probability of detection as if the sound source were 10 times more intense or less than half as far away. It has been estimated that a 1-dB gain in sensor performance costs about \$100 million in research and development.
- IMAT-trained crews showed significant performance gains on independent tactical readiness evaluations.

It is also notable that IMAT-based instruction not only can raise performance on already-established instructional objectives but also can raise the level of objectives sought in training. IMAT courses contain significantly more high-level (transferable, abstract, problem-solving) objectives and can cover all critical instructional components as contrasted with a sampling of instructional components covered by more conventional approaches.

⁸Wetzel-Smith, S.K., J.A. Ellis, A.M. Reynolds, and W.H. Wulfeck. 1995 *The Interactive Multisensor Analysis Training (IMAT) System: An Evaluation in Operator and Tactician Training*, NPRDC Technical Report TR-96-3, Navy Personnel Research and Development Center, San Diego, Calif.

Technology Reduces Time to Reach Instructional Objectives

The finding that technology reduces the time needed to reach instructional objectives arises repeatedly in reviews of instructional technology. Three independent reviews^{9,10,11} involving a total of more than 70 studies have found time savings ranging from 24 to 70 percent. On this basis, it may be reasonable to expect reductions in time of about 30 percent in general, across a variety of instructional objectives, through the use of instructional technology. Some studies may find smaller time reductions, but others have reported routine time savings of 50 percent in military technical training.

Students Enjoy Using Technology

Many evaluations of instructional technology simply ask students if they like this approach better than more conventional approaches to instruction. Practically without exception, students reply that they do. The long string of positive reports may be due to the novelty of using instructional technology. More conclusive findings must await more routine, frequent, and pervasive application of technology in education and training.

To return to IMAT, students are enthusiastic about IMAT-based instruction and rate it highly. On attitude surveys, students report a significantly greater ability of IMAT to hold their attention, address their needs and goals, build confidence in their ability to succeed, and increase their sense of reward and accomplishment. Instructors are typically slow to accept change in methods of instruction, but those using IMAT show levels of enthusiasm that are similar to those of their students.

Technology Lowers Instructional Costs

The costs of different instructional approaches are usually assessed by calculating the ratio of the costs of instruction using technology to the costs of instruction using conventional approaches. In these cases, the lower the ratio, the relatively less costly is the approach using instructional technology. Cost ratios are available for studies comparing initial investment costs and operating and support costs. A recent study¹² found that the ratio of costs for technology-

⁹Fletcher, J.D. 1990. *The Effectiveness of Interactive Videodisc Instruction in Defense Training and Education*, IDA Paper P-2372, Institute for Defense Analyses, Alexandria, Va.

¹⁰Kulik, J.A. 1994. "Meta-Analytic Studies of Findings on Computer-Based Instruction," *Technology Assessment in Education and Training*, E.L. Baker and H.F. O'Neil, eds., Lawrence Erlbaum Associates, Hillsdale, N.J.

¹¹Orlansky, J., and J. String. 1977. *Cost Effectiveness of Computer-Based Instruction in Military Training*, IDA Paper P-1375, Institute for Defense Analyses, Alexandria, Va.

¹²Fletcher, J.D. 1997. "What Have We Learned About Computer-Based Instruction in Military Training?" *Virtual Reality, Training's Future?*, R.J. Seidel and P.R. Chatelier, eds., Plenum Publishing, New York.

assisted approaches over conventional approaches in IVI was 0.43 for initial investment costs and 0.16 for operating and support costs.

In general, the cost argument for technology-assisted approaches is particularly strong when a \$2,500 general-purpose computer providing tutorial simulations can be used to achieve instructional objectives for operating, maintaining, or using real equipment costing one to three times as much. The substitution of two-dimensional computer-based simulations for experience with real equipment often turns out to be more rather than less effective than expected.

To return again to the example of IMAT, assessments¹³ have found the following:

- First-production IMAT course packages to date involve about \$10,000 in development costs per hour of instruction. This can be compared with conventional lecture instruction, which costs \$2,000 to \$10,000 per hour, and computer-based or multimedia instruction, which costs about \$10,000 to \$26,000 per hour. Highly complex content increases costs.
- New courses based on already available IMAT models and simulations (e.g., submarine predeployment training) cost only \$500 to \$2,000 per hour for development.

This sampling of results is neither comprehensive nor conclusive, but it strongly suggests that the application of technology in military training may be more effective and less costly than our current practice. It does not seem unreasonable, then, to argue that the resources needed for initial investment in these approaches may be well spent. These resources will include funding, time, and the effort to effect significant changes in professional practice and our instructional institutions.

BUDGETARY CONSIDERATIONS

Traditionally, budget decisions have tended to focus almost exclusively on the potential for savings within operation and maintenance (O&M) accounts. There are O&M savings to be gained from investments in converting from current training approaches to those that are technology based, but significant additional payoffs can be realized as well. These accrue from the reductions in time needed to train students when technology is used and the concomitant increase in the time that these individuals are available for duty. One difficulty is that although the investment needed to convert training programs will most probably

¹³Wulfek, W.H., J.L. Dickieson, J. Apple, and J.L. Vogt. 1993. "The Automation of Curriculum Development Using the Authoring Instructional Materials (AIM) System," *Instructional Science*, 21:255-263.

come from O&M accounts, major savings will appear in personnel accounts, not in O&M.

The net long-term payoff to DOD resulting from course conversion to technology-based instruction could be millions of dollars annually—but only when student pay is measured and considered in the analysis. The difficulty is that the savings can take different forms. The reduction in time spent away from the job site is an important factor that can increase productivity on the job, lead to future long-term efficiencies in the training infrastructure, and in many cases generate reductions in the personnel overhead accounts that pay for student time. Reductions in student accounts can be used to provide either (1) dollar savings, if end strength is reduced, or (2) additional military personnel to meet needs elsewhere in the force. As a result, it is necessary to quantify the potential payoff in terms of student pay as well as the O&M savings generated from distance learning investments.

That the investment may be worthwhile and that the costs of the investment may be recovered quickly, with significant cumulation of cost avoidance over the ensuing years, are suggested by the following rough analysis involving specialized skill training.

Reducing training time saves training resources, and as suggested above, it also increases readiness by providing capable personnel sooner to the naval forces. Savings in training time cumulated over thousands of students are a significant force multiplier. The following comments, which are intended to be more suggestive than conclusive, concern the application of technology to one area, specialized skill training.

Specialized skill training provides officers and enlisted personnel with the skills and knowledge needed to perform specific jobs. It is defined by the MMTR as initial, progressive, and functional training for officers as well as enlisted personnel. Specialized skill training includes such programs as Army Advanced Individual Training, Navy Apprenticeship Training, and Marine Combat Training. This training category also includes aviation-related ground training and initial enlisted leadership training other than that in professional development education.

About 620,300 Navy and Marine Corps personnel are expected to enter some form of specialized skill training in FY 1997, creating a training load of about 34,700 that will cost the Department of the Navy about \$2,098 million. Indirect costs for specialized skill training are more difficult to establish. Overall, they are about the same as the direct costs, effectively doubling the cost of such training. The total of both direct and indirect costs that would vary with student time spent in specialized skill training was estimated to be \$1,560.5 million, as outlined in Table 2.5.

On the basis of the information in Table 2.5, the panel assumed that about \$1,560.5 million will vary with the amount of student time spent in specialized skill training in FY 1997. Of this amount, \$789.2 million comes from costs for

TABLE 2.5 FY 1997 Navy Department Costs for Specialized Skill Training Expected to Vary with Time Spent in That Training (million dollars)

Cost Category	Navy	Marine Corps	Total
Operations and maintenance ^a	\$218.7	\$ 26.6	\$ 245.3
Active component student pay and allowances ^b	523.8	210.3	734.1
Base training support ^c			164.8
Direct training support ^d			46.6
Reserve pay and allowances ^e			55.1
Temporary duty costs ^f			314.6
Total			\$1,560.5

^aGiven by the FY 1997 MMTR, these costs are expected to vary with student time in specialized skill training.

^bEarlier MMTR data and a recommendation from the Defense Training and Performance Data Center suggest that about 35 percent of total Navy Department specialized skill training costs (Table 2.2 gives the estimated FY 1997 total) are for active component student pay and allowances.

^cThe amount of total Navy Department base training support costs expected to vary with student time spent in specialized skill training was estimated to be about 24 percent of the \$686.7 million total estimated in Table 2.2.

^dA similar percentage of total Navy Department direct training costs is assumed to vary with student time spent in specialized skill training (\$46.6 million of the \$178 million estimated for FY 1997 in Table 2.2)

^eSpecialized skill training will account for about 47.6 percent of the total anticipated FY 1997 Navy Department reserve component student load, and the portion of reserve component pay and allowances affected by student time spent in specialized skill training is thus assumed to be about 47.6 percent of the \$115.7 million estimated by the FY 1997 MMTR for reserve pay and allowances (Table 2.2). Additional cost savings—and improvements in reserve component readiness—resulting from technology applied in schools operated by the reserve components are also likely but are not considered here.

^fThe Defense Training Performance and Data Center has estimated that 15 percent of specialized skill training costs are temporary duty costs. Costs would also be affected by time spent in specialized skill training but are not included in this analysis. Of the \$2,097.6 million estimated for Navy and Marine Corps FY 1997 costs for specialized skill training (Table 2.2), \$314.6 million is expected to vary with time spent in training.

SOURCE: Compiled from data in *Military Manpower Training Report: FY 1997*, 1996, Office of the Deputy Under Secretary of Defense for Readiness, Department of Defense, Washington, D.C., July.

student pay and allowances, including reserve pay and allowances, and the remaining \$771.3 million comes from other training costs. Table 2.6 shows cost avoidances in student pay and allowances that are likely to accrue from various levels of reduction in specialized skill training time due to the introduction of technology for various portions of the student load. Cost avoidances in other specialized skill training areas that are likely to accrue from reductions in training time achieved by the introduction of technology are shown in Table 2.7. The reasoning underlying both Tables 2.6 and 2.7 is that not all students will be

TABLE 2.6 Potential Savings (Cost Avoidances) from Recovered Personnel Pay and Allowances Due to the Introduction of Technology in Navy and Marine Corps Specialized Skill Training (million dollars)

Percent Time Saved	Percent Training Load Covered			
	20	40	60	80
20	32	63	95	126
30	47	95	142	189
40	63	126	189	253

TABLE 2.7 Potential Savings (Cost Avoidances) in Training Costs Due to the Introduction of Technology in Navy and Marine Corps Specialized Skill Training (million dollars)

Percent Time Saved	Percent Training Load Covered			
	20	40	60	80
20	31	62	93	123
30	46	93	139	185
40	62	123	185	247

affected by the introduction of training technology and that different estimates for the amount of time to be saved should also be taken into account.

As shown in Tables 2.6 and 2.7, the cost avoidances that may result from the introduction of technology and reduction in the time needed by Navy and Marine Corps personnel to complete specialized skill training range from \$63 million (costs avoided for both direct training resources and pay and allowances combined by reducing time to train by 20 percent for 20 percent of the student load) to \$500 million per year (assuming 40 percent time reductions achieved by 80 percent of the students in specialized skill training). These are significant cost avoidances and may well justify the investment required to introduce technology into this training. Again, the difficulty is in accounting—the investments will come from one category, but many of the savings will appear in another.

Still, if this cursory analysis holds up under further scrutiny, the conversion of Navy Department training to the increased use of technology should be pursued sooner rather than later. By 2035 the training enterprise is likely to be modernized in any case, but the sooner that modernization occurs, the greater the level of resources that will be freed up.

Notably, the increases in readiness and effectiveness from these conversions remain to be determined, but they, rather than savings in costs, may be the most significant result of reducing the time to reach the human performance levels that are needed by operational forces and are the object of military training programs.

FLAG AND GENERAL OFFICER TRAINING

It is tempting to assume that flag and general officers, as the most senior of military executives, have reached a level of mastery that transcends any need for further education and training. Such an assumption is, in a word, wrong, and given the level of authority and responsibility held by general and flag officers can easily lead to disaster in the rapidly evolving environments of naval operations. Because of its capacity for privacy, technology-based training in individual technical matters may well appeal to these officer-executives. However, the new forms of technology-based training that involve linked simulations and can include force-on-force operations with levels of verisimilitude that seem to increase daily offer great promise in preparing flag and general officers for the operational environments of the future.

Four types of training are typically available to flag and general officers:

1. *Training for decision making.* In training for decision making, a real or simulated problem is typically identified. Participating officers provide their own staff support, as necessary (i.e., personnel officer, intelligence officer, operations officer, logistics officer, and other special staff). The host command for the decision-making training provides a series of necessary questions that, when answered, can lead to a logical decision. Each question is tackled by each participating flag officer and support staff team. After a designated time (innings), the officer presents to the participating group an answer to the question. The presentation follows the course-of-action format (problem, analysis, conclusions, recommendations) and is tightly controlled by time. After the various innings described above, the original problem is addressed with the information developed in the intermediate question session. The host command then summarizes the recommended decision and forwards it to the convening authority.

2. *War gaming.* Participants in war gaming may be single Service, joint or combined, or multinational. The host provides a general and a special situation, generally describing a geopolitical international crisis by addressing the background, cause of tension, increase of tension, and spread of conflict. Flag and general officer participants often represent the commands they would be expected to use in the crisis. They are supported by staff appropriate for a real-world operation. The scenario is broken down into phases, moving forward from response to tension up to the advent of war and initial operations. Commander-staff interactions develop decisions affecting the represented commands, ranging from precrisis deployments to war employments. A war game control group

evaluates the various gaming moves and decisions and modifies the game's scenario based on the actions of various participants. Staff challenges are interjected into the scenario. All staff have responsibilities and often DOD and other federal government agencies participate. War games help flag and general officers become aware of the tremendous coordination required to undertake military operations and of the often unintended results of major decisions.

3. *Crisis action.* This type of training is similar to war gaming, except that the scenario does not involve execution of a major war plan. Generally, the scenario evolves from an international crisis for which no general war plan exists. The demands of the crisis stimulate original thinking, adaptability, coordination, and often new and unique concepts for the deployment and employment of U.S. forces (e.g., U.S. Army rotor assets on aircraft carrier platforms).

4. *POM cycle and POM decisions.* A real-world demand within established DOD-Navy processes caused the former commandant of the Marine Corps to make effective use of his general officers to aid in program objectives memorandum (POM) decisions. A format similar to the one described above in training for decision making was used, except that each general officer participated with fewer support staff. Of particular significance were the various tradeoffs and decisions that had to be made based on Service missions, ongoing programs, R&D efforts, departmental decisions, and warfighting capabilities and support.

It is not difficult to see how technology would assist in delivering these types of training. Technology-based, distributed simulations will be especially valuable for busy, high-level military executives if participants do not have to be physically assembled for the training and can participate from widely dispersed locations worldwide. These capabilities are now within the state of the art at fairly basic levels. They will improve substantially in the future and will be used for other levels of training. There is little reason to deny their benefits to our most senior decision makers.

TRAINING MODERNIZATION

If the modernization of Navy and Marine Corps training through technology is likely, it may be worthwhile to speculate on the forms this modernization might take. In general, the training capabilities that are sought should be accessible, effective, and efficient.

- Training should be accessible.

- Training should transcend physical location so that it is available wherever it is needed or wanted. Training should be available in schools, homes, workplaces, and learning centers. Environmental constraints should be minimal.

- Training should transcend time so that it is available whenever it is

needed or wanted. Scheduling of training resources, equipment, materials, and/or instructors should not constrain the time at which training can be accessed.

— Training should transcend physical devices so that it can be portable. Constraints imposed by delivery platforms should be eliminated.

- Training should be effective. It should do the right things. It must be relevant (1) to the job to be performed and (2) to the individual who is to perform it. Training analyses should be done in real time to set skill and knowledge objectives specifically tailored to the skills and knowledge that an individual needs.

- Training should be efficient. It should do things right. Once relevant objectives are chosen, the instructional approaches used to meet them should be the most cost-effective available for the individual being trained.

Given that these capabilities are sought in training, what sort of goals should be set for developing them? It may be best to base goals on extrapolations from what is now embryonic in technology applied to training but has been launched and is likely to continue. Three areas of development that seem likely to change the nature of training are (1) embedded training, (2) modeling and simulation, and (3) intelligent training systems. Technology-based training capabilities expected to be available in 2035 are listed in Table 2.8, along with the key enabling technologies that will make them possible. The capabilities described in Table 2.8 are evolutionary, not revolutionary. Although it is always possible that a scientific or technological breakthrough will overshadow these developments, they are nevertheless likely to occur.

Given the heuristic of extrapolating from these areas of training R&D and from other developments that will have an impact on training technology, goals for technology development applied to training might be realistically established for five areas of capability: (1) portability; (2) interoperability in preparation of materials; (3) aids for delivery of instruction, including tutoring capabilities; (4) instructional intelligence; and (5) integration of instruction into current institutions (Table 2.9).

Development of portability will provide interactive courseware with the same operating capability—plug and play—now available in high-fidelity audio systems. Authoring system interoperability will permit interactive courseware written using one authoring system on one suite of equipment to be freely modified using another authoring system and another suite of equipment. Development of aids for instructional delivery will provide everyone with a so-called Ph.D. in a pocket—an expert, articulate advisor that will provide information for decision making and performance advice that the student or user can understand and apply. This advice will be delivered on a device comparable to early pocket calculators. Distinctions between instruction and advice will be very difficult to draw. Development of instructional intelligence will provide individualized tu-

toring that integrates the setting of training objectives, job performance aides, and performance assessment into a single package. Natural language interaction will be an essential feature of this capability—there will be an Aristotle for every Alexander and a Mark Hopkins for everyone else.

Integration of technology-based instruction into the routine, daily practice of existing instructional and workplace institutions will be the most difficult challenge. The goals, organization, and functioning of these institutions will all be modified to take advantage of the technology. Just-in-time training that is available to everyone will change not only the ways human resources are managed in the workplace but also the workplace itself.

TRAINING SUMMARY

The application of advanced technologies for education and training is key to developing and sustaining the levels of human performance necessary for naval force effectiveness. Currently, the Navy has at least three significant opportunities to improve the efficiency and effectiveness of its education and training activities: (1) capitalize on the efficiencies available from applications of multimedia, interactive technologies such as interactive distance learning, embedded training, intelligent training systems, and collaborative virtual environments; (2) capitalize on the efficiencies available from increased outsourcing; and (3) leverage and find common cause with the research, development, and acquisition activities that exist outside the Department of the Navy—in the other military Services and across federal agencies, at all levels of government, and in the private sector.

Comparisons of technology-based training with more conventional approaches have found that its use can raise student achievement by 15 percentile points, that it reduces time to reach given instructional objectives by about 30 percent, that it lowers costs of training for equipment operation and repair by about 40 percent, and that students generally prefer it. It also makes training more accessible. Use of CD-ROM or newer digital videodisk (DVD) technology to provide training aboard ships and at other dispersed locations can overcome residential classroom limitations of both time and place.

A natural application of technology-based training is in specialized skill areas. If 20 percent of Navy and Marine Corps specialized training students were to use technology-based training to reduce training time by about 20 percent, the savings in training costs and student pay and allowances would amount to many millions of dollars per year. These economic benefits exclude the improvements in readiness that might result from 20 percent earlier graduation of students from training.

Despite their promising indications, the current use of these technologies in

TABLE 2.8 Technology-based Training Capabilities Expected to Be Available in 2035

Capability	Description	Key Enabling Technologies	Goal
Embedded training	Training for operation, maintenance, and/or employment of a system (e.g., device, software package) included in, and presented by, the system itself	<ul style="list-style-type: none"> • Human-computer interaction • Information access and decision support technology • Cognitive modeling 	<ul style="list-style-type: none"> • Obviate requirements for external training: potential user should need only to turn the system on to learn how to use it—all operator and deployment training should be embedded, as should most maintenance training • Ensure separation of training from operations and noninterference of one with the other
Distance learning	Structured learning that takes place without the physical presence of an instructor. Distance learning refers to distance training, distance education, distributed training, etc., and includes the full range of approaches (not just video teletraining) for distributing instruction to physically dispersed students	<ul style="list-style-type: none"> • Computer and video communications • Data compression • Networking • Interactive courseware (e.g., computer-based instruction, interactive multimedia instruction, techniques of individualization, design to effect specified outcomes) 	<ul style="list-style-type: none"> • High-quality training available anytime, anywhere, to any student • Integration with personnel, classification, and assignment systems
Interactive courseware	Training delivered using computer capabilities that tailors itself to the needs of individual students	<ul style="list-style-type: none"> • Computer technology • Cognitive modeling • Instruction engineered to achieve specified training outcomes 	Training that uses interactions with each student to maximize its efficiency by tailoring sequence, content, style, and difficulty of instruction to the needs of that student
Intelligent training systems	A form of interactive courseware that is generated in real time, is	<ul style="list-style-type: none"> • Speech and natural language interaction 	<ul style="list-style-type: none"> • An articulate, expert tutor for every student, possessing full knowledge of the

	tailored to the needs of the individual student, and permits initiation of a tutorial dialogue and open-ended questioning by the student	<ul style="list-style-type: none"> • Cognitive modeling • Knowledge representation • Computer technology 	<p>student, the subject matter, and tutorial techniques and capable of sustaining mixed initiative, tutorial dialogue in terms the student understands</p> <ul style="list-style-type: none"> • "An Aristotle for every Alexander"
Simulation	Representations of real-world systems, situations, and environments that help achieve specified training objectives	<ul style="list-style-type: none"> • Digital, multimedia displays • Fidelity matched to training objectives • System, situation, and environment representation • Knowledge representation 	<ul style="list-style-type: none"> • Device representations for maintenance and operator training generated directly from computer-aided design databases • Representations of interpersonal situations that respond to student decisions and actions • Representations of environments that convey sufficient psychological reality to achieve specified training objectives
Virtual reality	A form of virtual simulation—sensory immersing representations of real-world environments	<ul style="list-style-type: none"> • Digital, multimedia displays • Multisensory displays • Real-time interaction 	<p>Environmental representations providing full psychological reality and sufficient physical reality selected to achieve training outcomes</p>
Engagement simulation	Simulations providing live, virtual, and constructive representations of real-world warfighting environments	<ul style="list-style-type: none"> • Networking • Data communications • Digital, multimedia displays 	<p>Seamlessly linked simulations supporting simulated environments in which engagements occur continuously against "real" and semiautomated forces</p>
Human performance assessment	Assessment of relevant performance capabilities of individuals and teams	<ul style="list-style-type: none"> • Psychometrics of simulation • Job-sample testing • Assessment of cognitive processes 	<p>Valid (measures the right thing), reliable (measures things right), precise (exactly identifies progress toward learning objectives) assessment of the knowledge, skills, and attitudes of individual students and teams available at any time in a training program</p>

TABLE 2.9 Planned Training System Capabilities for Interactive Courseware

Technical Capability	By 2000	By 2015	By 2030
Portability	System-level interoperability	Device-level plug-and-play interoperability	Authoring system interoperability
Instructional materials preparation and "authoring"	Object-based authoring from object repositories	Knowledge-engineered capture of subject matter and instructional expertise	Automated generation of simulations, job aids, and instructional guidance from interoperable CAD databases
Instructional delivery	Expert system-based tutor	Individual tutoring and job-aid expert on a desktop	<ul style="list-style-type: none"> • Individual tutoring and job-aid expert in a pocket • Natural language understanding and interaction • Individual tutor and expert assistant embedded in every complex device
Instructional intelligence	Information management	<ul style="list-style-type: none"> • Automated instructional design • Integrated tutors and simulation • Intelligent agents embedded in virtual environments as aids, surrogates for missing team members, and opposing and friendly forces 	<ul style="list-style-type: none"> • Immersive, virtual environments • Expert tutors using natural language
Institutional integration	Widespread access to national information infrastructure	<ul style="list-style-type: none"> • Seamless school-to-work transitions • Networked interactive simulation for situated apprenticeships 	<ul style="list-style-type: none"> • Journeyman-level training available in all settings

naval training is minimal. Available records¹⁴ indicate that of the 3,139 courses presented by the Navy in FY 1997, only 47, about 1.5 percent, used interactive instructional technology. An additional 49 courses were taught using video teletraining to accomplish learning at a distance. Overall, technology-based approaches are unlikely to be found in more than 4 percent of all Navy and Marine Corps training. It may be time to increase their use. Considerable leverage will be gained if the Navy and Marine Corps and the other Services cooperate in developing and expanding use of these technologies in training. Investments in these technologies are likely to increase substantially both the effectiveness and the efficiency of training, to yield significant returns that can be used to fill existing gaps in the delivery of training, and to increase the pace of training modernization. Moreover, the technologies in question can collect data on individual and collective performance that could be used by local commanders in determining the composition of small teams.

Outsourcing is a high-priority concern within DOD. Recent studies^{15,16} have found that costs to produce instructional materials and operate networked training simulations may be lowered and fewer instructional personnel may be required when outsourcing is used. Outsourcing cannot be applied universally in Navy and Marine Corps training, but it can produce significant economies in obvious areas such as specialized skill training or the delivery of education and training that is already available from community colleges and trade schools.

Finally, the Department of the Navy could join with other federal agencies and the private sector to leverage the development of performance and certification standards for jobs and occupational areas of common interest and to establish technical standards for the reusability, portability, and interoperability of technology-based courseware. These actions will significantly increase the value and quality of training materials available from suppliers.

Specific investments in research and development applied to training can yield large returns. For example, team training research is still in its infancy; much has to be done to learn how to properly characterize what a team is, how to measure team cohesion, and how to instill team cohesion efficiently. To insert technology into the training enterprise in a time of cost constraints, it will be necessary to understand how much fidelity is required to achieve a desired degree of training transfer and use this measure to drive the requirements for a given technological training solution. As the Navy moves to greater use of distributed

¹⁴These records are available from the Defense Instructional Technology Information System (DITIS), which is maintained by the Defense Manpower Data Center, Washington, D.C.

¹⁵Tighe, C., and S. Kleinman. 1996. *Outsourcing and Competition: Tools to Increase Efficiency*, Center for Naval Analyses, Alexandria, Va.

¹⁶Metzko, J. 1996. *Government vs. Contractor Training at the U.S. Army Signal Center*, IDA Document D-1942, Institute for Defense Analyses, Alexandria, Va.

training and applies it to collective training, attention must be paid to interaction over communication channels.

Thus, an investment must be made in research into the nature and technological implications of human interactions within shared virtual environments. The movement of training closer to the time of its utilization will also characterize the future training of naval forces. One can foresee a time when a decision to deploy a force rapidly, generate the necessary training content for mission-specific rehearsal, and deliver that training in transit to the operational site can all be accomplished within a single 24-hour period.

Combat Medicine

Provide for significant advances in the development and application of medical technologies for reducing combat casualties and deaths.

THE COMBAT MEDICAL ENVIRONMENT

When it is required, combat care is needed immediately, often in remote locations and under the most stressful conditions. During small contingency actions—in the Lebanon- and Somalia-type operations that are likely to occur in the future and allow little public tolerance for casualties—immediate, high-quality combat care is required. A sophisticated combat medical capability has become a necessary part of military missions with diplomatic and political consequences. This continually evolving role places increased pressure on the Navy to be able to respond to all contingency operations with immediate combat care. The current Gulf War medical debate illustrates how new weapons (chemical and biological) may be available to almost every adversary nation, and the Navy should be prepared to respond as new combat treatments are required. Combat care—particularly urgent battlefield care—should be given priority in DOD and Navy Department medical investments and in new technology development. Medical career patterns in the Navy should be modified to emphasize the importance of combat medicine capability and experience.

The first defense against the effects of hostile fire, disease, and lethal environmental agents is a continuous process of maintaining a healthy, physically fit, and psychologically resilient force. Major advances in physiological preparedness are anticipated. Today, the Navy relies on exercise, diet, routine physicals,

and after-the-fact urgent medical care. By 2035, it should be possible to have full wellness programs with continual monitoring of many physiological and psychological processes, job-specific performance enhancers, and genetic testing for physiological and behavioral strengths and vulnerabilities. Moreover, advances in biomedical and behavioral sciences may salvage a significant number of persons who are currently excluded from military service because of physical or psychological problems.

In combat, the process of medical prevention and treatment will continue with the aid of special devices and procedures that have been designed to enhance protection from, or provide immediate treatment for, injuries resulting from battlefield hazards. These hazards include direct enemy action as well as dangers imposed by the hostile environment.

It is important to have a medical system in place through telemedicine that enables the connection of remote sites (ships, battlefield) to medical facilities located in the continental United States (CONUS). Naval operations in 2035 will pose new types of antipersonnel threats combined with the familiar threats of explosive devices and projectiles. The new threats will include chemical and biological warfare agents delivered by artillery, bombs, rockets, or missiles, and directed-energy weapons such as lasers, high-powered microwaves, radio-frequency waves, and other forms of nonionizing as well as ionizing radiation.

Also likely is the addition of environmental and geographical extremes associated with contingency operations that require U.S. forces to deploy to remote areas of the world. Fighting in these areas carries with it the added significant threat of infectious diseases, a special form of environmental hazard.

Finally, future operations will expose naval forces to extraordinary levels of psychological stress resulting from highly accurate and lethal weapons; silent and deadly chemical or biological agents; equally silent and dangerous directed-energy devices; sustained operations; increased dispersion and isolation of small units; and the uncertainty of contingency operations in remote areas.

PROTECTION AND PREVENTION

One major concern of military medical departments is specialized preventive measures. These include drugs and vaccines to protect our forces against nuclear, chemical, and biological agents; physiological monitoring of body temperature, hydration, and alertness; specially designed ensembles for protection from projectiles, directed-energy devices, and chemical and biological agents; and psychological aids, such as land navigation and local communication devices that enhance security and provide information regarding available support. The Department of the Navy should seek to integrate lightweight body armor into its combat forces so that each sailor or marine within a group will be wearing unencumbering body armor with an integrated personal status monitor. This will provide real-time updates of combat personnel status.

By 2035, U.S. naval forces should be able to provide significantly enhanced protection for individuals in all combat situations. Although the United States will face more varied biological and chemical threats, it should be possible to counter those threats with genetically engineered solutions and better antidotes. The ability to deploy effective countermeasures further depends on an accurate assessment of the threat, and a comprehensive threat assessment capability should be a critical element in the Navy's suite of preventive and protective countermeasure capabilities. The Department of the Navy has an opportunity to leverage ongoing advances in protein analysis and chemical and biological assay sensors (e.g., biosensors on a chip) by supporting the development of these technologies for Navy- and Marine Corps-specific applications. In particular, technology development will be required to realize the reliable performance of these devices under combat conditions. The expected availability of a complete DNA analysis for individual service personnel will facilitate the design of individually tailored countermeasures to anticipated chemical and biological assaults.

By 2035, the United States will be able to replace today's cumbersome and marginally effective mission-oriented protection posture (MOPP) gear, flak jackets, and helmets with flame-retardant environmental suits and lighter, smart body armor. Eye shields will be greatly improved to counter the anticipated use of more blast, high-energy particle, and burn injuries in the future. Mechanical and electronic devices for blocking or canceling energy that affects the visual or auditory systems will also be available to protect individuals from a variety of high-energy sources (blast, laser, microwave, vibration, and sound energies). If better information is available on the potential threats faced by U.S. forces, appropriate modification of body armor and other forms of protection for individuals should be possible through the use of adaptive information systems.

Physical protection that includes impregnable uniforms and protective masks is essential, but advanced technology threats will require the application of even more advanced technology to counter them. New protective technologies will include fabrics with selectively permeable membranes that exclude threat agents but allow individuals to hear, see, move, breathe, and perspire normally. A second, perhaps more effective, approach for some threat agents is the administration of physiologically protective drugs—either immunological or passive scavengers—that block or neutralize the adverse effects of entire classes of threat agents. Protective clothing, or body armor, will be able to provide medical intervention by administering these physiologically protective agents on demand or as indicated by sensors built into the clothing. It will also be able to warm or chill the wearer, inject hemostatic agents, and apply fiber-type glue to wounds as needed. Finally, it will be able to bear weight and supplement some body movement and large muscle function, as needed. The Navy and Marine Corps have a direct interest in the availability of these capabilities, but little research funding is currently allocated to their development. The Navy Department should consider treating the development of these capabilities as a research priority.

CASUALTY ASSESSMENT, CARE, AND EVACUATION

Combat inevitably causes casualties that require immediate assessment and sophisticated medical care of an injury at far-forward positions. By 2035, physiological surveillance will be greatly enhanced through the use of sensors and personal status monitors. The use of telemedical technologies will allow medical and paramedical personnel to perform many more of the procedures required within the first 30 minutes of injury. Telemedicine has multiple levels from CD-based to Internet store and forward (non-real time) to telesurgery. It should be possible to provide just-in-time surgery anywhere and anytime. The capability to provide effective and immediate treatment on the battlefield at or near the site where injury occurs will save lives. This capability will become increasingly important to ensuring rapid recovery that serves to minimize mission impact and avoid permanent disability.

As discussed above, naval operations will involve dispersed, independent units located far from friendly medical care facilities. The time, people, and facilities available to care for casualties will be severely limited. This situation will be particularly serious given the narrow window of opportunity available to care for serious wounds and injuries. About 90 percent of deaths in military operations occur in the first 30 minutes, when often the only care available comes from the casualty victim him- or herself, a buddy, or a corpsman.

Immediate care of casualties requires precise information on the location and physiological status of wounded or otherwise incapacitated personnel. This information is essential if medical care is to be effective in minimizing losses; the same information is also critical for timely command decisions regarding the status of engaged forces for continued operations or the need for replacements or unit reconstitution. In the past, the Department of the Navy has used a medical care approach based on echelons of care. In the future, it will use an approach that defines levels of care in terms of time frames ranging from hours to days. This will allow improved use of resources and concentration on clinical capabilities.

Today, the Navy and Marine Corps medical units depend on line of sight, personnel accounting, and radio communications. By 2035, all individuals are likely to have personal status monitors that provide both precise location and physiological assessment information. In addition to the individual's voice channel, the monitor inputs will include indicators of heart rate, respiration, body temperature, skin resistance, arterial blood pressure, stress, and alertness.

In the past, the military has actually developed personal status monitors, but their deployment was not continued due to insufficient testing. The availability of a personal status monitor would add valuable capability to both current and future operations.

The fluidity and rapidity of military action and the dispersed character of the future battlefield will influence the type and location of facilities for medical treatment. The emphasis will be on compact, lightweight, highly mobile medical

facilities for diagnosis and forward medical treatment and on extensive digital signal processing and computer utilization, including medical databases. Among the needs of the combat medical system are field medical devices; new battle dressings; filter absorption systems; on-site oxygen production or conversion; improved venous access devices; improved peripheral perfusion and ischemia monitoring; and self-calibrating in vivo blood gas, pH, and electrolyte monitors.

MEDICAL TECHNOLOGY

Many promising technologies under development or on the horizon could help improve combat and battlefield care. Although many of the emerging technologies have a dual use for both combat and civilian medical practice, some of them should be pushed for early evaluation for combat medicine. Among the capabilities needed are medical databases that record an individual's medical history and are coupled to a monitoring system. The sailor or marine should have a medical history and patient-specific virtual human body model built into the memory of his or her suit and entered in the medical information system.

Already available for use are new battle dressings in the form of self-contained antibacterial gels for application to burned skin. They provide protection from further damage to the skin as well as relief from pain. The dressings are designed so that they expand with moisture derived from the air when the packet containing them is opened. They can be incorporated directly into the body armor and released automatically.

Both filter absorption systems and on-site oxygen production will be important to the combat medical system. The absorption systems will be used for on-site production of sterile fluids, including intravenous fluid. Although on-site oxygen production or conversion is not yet possible, it is anticipated that in the future enhanced technological developments will provide this capability.

To reduce the complications of infection, phlebitis, or thrombosis, improved venous access devices will be required. The results of initial trials of one such device have been promising and have shown no adverse effects for test periods of up to two weeks. Problems that have to be resolved relate to the rigidity of a metal needle and to electroplating with the least irritating metal surface.

Improved monitoring of peripheral perfusion (blood flow through tissue) and ischemia (localized tissue anemia resulting from obstruction of the inflow of arterial blood) will be used to enhance shock trauma management. Most investigators and experienced clinicians accept a definition of shock as a persistent state of poor peripheral perfusion. Today, evaluations of the severity of shock can be made only on a clinical basis, supplemented with indirect laboratory measurements. By 2035, more direct assessment of peripheral perfusion will be possible. The personal status monitor will be able to provide thermistor-polarographic sensing that combines measurements of temperature (as an index of tissue perfusion) and oxygen tension (as an index of tissue ischemia). The monitor will also

allow measurement of oxygen tension to be correlated with perfusion. In contrast to the current state of the art (i.e., microbeads used to assess perfusion), the personal status monitor will allow on-line readings to be repeated indefinitely. The personal status monitor will be integrated into the overall health care delivery system. This will allow care providers from the front line to CONUS to better handle medical logistics and decision making.

Personal status monitors will also provide self-calibrating in vivo blood gas, pH, and electrolyte measurements. A limitation of current instruments for continuous monitoring of blood gases and pH is their requirement for frequent and recurrent calibration. They are also invasive and require frequent sampling of blood. Current noninvasive instruments are less reliable and depend on cutaneous circulation. These disadvantages will be circumvented by development of a membrane for a disposable intra-arterial device that continuously monitors arterial oxygen pressure, arterial carbon dioxide partial pressure, pH, and electrolytes and requires no laboratory calibration or removal of blood. By the year 2035, these devices might possibly be implanted or swallowed. Mind-machine communication used to control devices for transporting micro-sensors throughout an individual's body may become a significant tool for aiding self-assessment and diagnosis in 2035.

Bandaging material that is impregnated with new hemostatic agents and can be inserted into a wound will control most bleeding. The only exception would be hemorrhage from a major vessel, which might require a tourniquet, depending on its location. Often, troublesome bleeding is not from a major vessel but is the continuous, significant hemorrhaging of many smaller vessels. Hemostatic wound dressings combined with small-volume, stable, concentrated oxygen-carrying fluid will also reduce shock in combat casualties. Major hemorrhaging can be stopped with an automatic response from body armor acting as a tourniquet. Robotic-directed catheters based on the patient-specific virtual model can be placed peripherally to stop major vessel bleeding centrally. Monoclonal targeted antibodies can be used for topical therapy of wound infections and burns.

By 2035, artificial skin and bone will be available as tissue substitutes to facilitate wound healing, burn control, fracture stabilization, and prevention of permanent disabilities. A combination of synthetic and biological materials that replicates the role of the epidermis makes up membranes that are now in clinical trial. They will certainly improve throughout the next 30 years. Reconstitution of the dermis, based on seeding cells from the patient's skin into the membrane, is currently at the research stage. It appears to replicate normal tissue and significantly reduces contractures. These same techniques offer promise for forming epineural sheaths to guide axonal growth in peripheral nerves and to use in blood vessel prostheses. An alternative approach may involve replication of the patient's own skin cells on the massive scale necessary to produce adequate coverage. This approach can also be used for whole organs or limb replacements, as well. It should also be possible to make better replacements for organs or

limbs through the use of tissue engineering. Alternatively, it may make sense to stockpile animal organs to be used to replace vital organs just as blood is now stored and made available. Animal organs may be used extensively for this purpose by 2035.

Artificial blood vessels may meet the challenges of smaller vessel prostheses. The integrated construction of the prostheses will prevent the complication of fibril shredding that is characteristic of adhesively bonded fibril surface systems. Because the bulk mechanical properties of the graft are determined principally by the solid nonporous substrate, the desired graft compliance may be achievable by simply adjusting substrate thickness.

Cultured skin grafts and cultured epidermis for the treatment of massive burn wounds are still a topic of controversy, even though the technique for covering burn wounds with cultured cells has been available since 1984. A recent study, however, demonstrated a significant reduction in both morbidity and mortality in patients suffering from burns on 40 percent or more of their body who were treated with cultured keratinocytes.

By 2035, endotoxin vaccines may be available for the treatment of shock to prevent the development of toxins during prolonged severe hypoperfusion of tissues during shock. Recent evidence shows that the toxin in the gut stems from loss of the barrier function in the hypoperfused area. This permits the migration of toxins, or perhaps whole bacteria, across the gut wall and into the circulatory system. Hypoperfusion also damages the reticuloendothelial system and diminishes its protective barrier. Entrance of a toxin or of bacteria into the circulation may be the primary cause of the pulmonary complications or multiorgan system failure responsible for most deaths after prolonged shock. Prevention of these life-threatening consequences of shock will require rapid and adequate restoration of circulatory volume, the use of broad-spectrum antibiotics, and some type of vaccine to neutralize the effects of liberated toxin. Nutrition to protect the liver and the gut barrier function also is a vital area for examination.

Various pharmaceutical developments will enhance the combat medical system:

- Drugs will assist in more rapid recovery from acute stress reactions.
- Pharmaceutical agents will induce hibernation in casualties to suspend deterioration while patients await definitive diagnosis and treatment.
- Means will be developed to protect individuals against biological and chemical agents and to detoxify them as needed.
- Microencapsulated antibiotics with the capability of providing sustained, high local levels and minimal systemic levels of antibiotics will be implanted as needed.
- Direct administration of drugs by protective suits or remotely by telemedicine will be possible.

Finally, it will be possible to relieve today's heavy reliance on corpsmen to some extent by the greater self-reliance of individuals in diagnosing and treating their injuries and in communicating information about their status and treatment to medical center personnel.

Telemedicine systems will be prevalent and will augment the skills and knowledge of medical personnel in the field. These systems will support acute-care decision making by frontline personnel through the use of video capabilities and medical instrumentation that enable communication with medical experts in distant locations. This development will affect the way casualties are handled, the way acute care decisions are made, and the way medical personnel are selected, assigned, and trained. In addition, the professional isolation of service personnel stationed away from academic medical centers can be reduced by offering the face-to-face connectivity, database access, and continuing medical education available from these telemedicine systems.

It is unlikely that telemedicine systems, even in 2035, will go so far as to provide sufficient capacity, portability, durability, and, especially, tactical security to allow real-time, on-line telesurgery in an acute-care, field setting. However, use of these systems to support personal status monitoring, trauma care and decision making, threat assessment, and other biomedical applications is likely. The many advantages, including financial, that are presented by the deployment of telemedicine systems are significant. Study of these evolving systems to analyze their development, use, and placement would yield significant returns to the Navy and Marine Corps and should be pursued.

The resuscitation technologies described above will be paired with improved equipment and procedures for evacuation. Casualties will be pressure-suited or placed in protective cocoons, if necessary, to maintain blood pressure. They may then be evacuated using encapsulated, mobile robotic platforms that provide both environmental protection and physiological monitoring. There will be a continuous care system based on levels of care and a time frame starting in the far-forward battlefield with a smart body suit. The injured person will be transferred to a smart structure that will fit into a trauma pod. This pod will be mounted in a mobile land-based operating room (armored ambulance) that can be transported to a mobile airbase operating room for transport back to the next level of care on board ship.

These capabilities for treating casualties will be well within the state of the art in 2035. Whether or not they are actually available to naval forces and supported by people who can use them well will depend on the extent to which the Department of the Navy emphasizes combat medical care capabilities—care that can be provided in the first 30 minutes.

The Department of the Navy should accelerate and support R&D in combat medicine that focuses on integrated protection and monitoring systems, on at-sea medical systems using telemedical capabilities, and on advanced pharmaceutical products that are effective against new battlefield weapons. Naval combat medi-

cal capability should be enhanced through the development of a battlefield threat assessment and response system. Development of such a system should include biotechnology R&D focused on improved methods for early detection, identification, and countermeasures to prevent or neutralize the adverse effects of chemical, toxin, or biological threats; to counter nuclear and directed-energy threats; and to reduce the risks from environmental hazards. Timely and effective response to new threats depends on making the knowledge of potential threats and countermeasures available to the combat medical specialist. Finally, and most importantly, the Department of the Navy should place much more emphasis on the pursuit of combat medicine capability in its medical caregivers and should reward those who specialize in combat medicine more fully in accord with its value to our naval forces and naval operations.

Innovative military medicine, focused on serving its customer, the combatant, has the potential to become the benchmark for a responsive U.S. health care delivery system. There are important cultural enablers to achieving greater levels of survivability in 2035. They require (1) integration of combat and medical elements in planning, (2) improvements in the requirements process for field medicine, (3) better career paths for combat medical personnel and specialists, (4) dedicated funding for combat medicine, and (5) a specialty that focuses on combat medicine with its own training program.

In brief, the Department of the Navy should place additional resources and focus on combat medicine and on the technologies that enhance the effective delivery of medical care anytime and anywhere. In achieving this end, the Navy will substantially improve the care of those most deserving its attention. Moreover, by better ensuring the presence of naval force personnel when and where they are needed, investment in survivability is a major force multiplier. Such investments will be repaid directly in increased force readiness and effectiveness where they are most needed.

Quality of Life

Strive for a duty, career, and personal life environment that increases retention, enhances readiness, and promotes performance.

"Quality of life, as a term, is difficult to define comprehensively. Each service member may evaluate the quality of his or her life in somewhat different terms. Basically, the term embraces the human dimensions of service life—the environment in which our people work and live."¹

The Navy and Marine Corps are voluntary organizations and will remain so into 2035. As such, they must compete with civilian employers, as well as the Army and Air Force, to recruit and retain a work force by providing not only a competitive compensation package but also a set of duty and living conditions, educational and training programs, and career opportunities that are comparable to civilian activities. Military service has certain unique characteristics, most notably a requirement for commitment to service and sacrifice that extends well beyond most civilian occupations. This commitment often requires members to leave home and loved ones for extended periods and occasionally exposes members to the hazards associated with military operations—including combat. Military members live by a code of behavior more demanding than that required of the average citizen. These unique demands require military leaders to seek ways to deal with the special stresses inherent in a military lifestyle and career.²

¹Tice, R. 1991. "Testimony Before the Defense MILCON Appropriations Committee," Washington, D.C., February 18, pp. 420-425.

²Segal, M.W. 1986. "The Military and the Family as Greedy Institutions," *The Armed Forces and Society*, 13:9-38.

The human dimensions of service life—what is defined broadly as *quality of life*—are critical components for achieving military retention, readiness, and performance objectives. Although “the actual details of the future will always be different from what we envision,”³ the realization of a smaller, smarter Navy and Marine Corps and implementation of the technological developments anticipated in the next half-century will not diminish the importance of quality of life (QOL) provisions for sailors, marines, and their families. Changes in how QOL priorities are ordered by individuals and families and how they can best be delivered should be expected. To adapt to these changes, the Navy and Marine Corps must be both flexible and cognizant of the complexity of human needs and the interrelationships among military duty and personal concerns.

The Department of the Navy invests significant resources to provide for the well-being of its members and families in the form of compensation, benefits, and services. As noted in a recent Defense Science Board report,⁴ QOL expenditures are a significant part of the overall defense budget, with specific DOD installation programs costing more than \$6 billion per year and overall housing expenditures representing more than \$11 billion. The Navy’s (not including the Marine Corps) 1998 budget request includes \$22.6 billion for broadly defined quality of life.⁵ This includes \$13.2 billion for pay, \$4.6 billion for medical care, \$3.3 billion for shelter, \$1 billion for exchanges and commissaries, and \$0.44 billion for traditional installation-based QOL programs (morale, welfare and recreation, child care, voluntary education, family services, legal and chaplain services, and so on). These proposed expenditures do not include funds that will be spent to enhance the duty environment of service personnel or funds invested in their military skill and career development.

Navy QOL strategies for the 21st century require an expanded examination of the relationships between QOL investments and militarily relevant variables. This analysis must take into consideration assumptions about the future Navy and Marine Corps and their mission in the 21st century, possible effects of emerging technologies on QOL, ways in which various demographic and social changes may affect QOL perceptions, and evolving procedures and methods for delivering cost-effective human services.

³Buder, S. 1990. *Visionaries and Planners: The Garden City Movement and the Model Community*, Oxford University Press, New York.

⁴Defense Science Board. 1990. *Achieving an Innovative Support Structure for 21st-Century Military Superiority: Higher Performance at Lower Costs*, Office of the Under Secretary of Defense for Acquisition, Department of Defense, Washington, D.C., November.

⁵Eltringham, R. 1997. Personal communication, Navy Quality of Life Program Office, Washington, D.C.

THE ROLE OF QUALITY OF LIFE

Today, quality of life is thought of as a multidimensional concept, defined as factors that promote physical, psychological, and social well-being, as determined both by the actual environment and by the perceptions of individuals.⁶ The way individuals perceive their lives overall is typically measured as the sum of their feelings about a number of different domains (or aspects) of life, combined in a linear fashion.⁷ The set of subjective QOL domains that corresponds with General Tice's human dimensions of service life includes the perceptions of duty and career matters, socioeconomic issues, and family and personal concerns. This cluster of domains has been found to be relatively stable across individuals and over time. Such stability implies that Navy personnel and their families will continue to be concerned with the same facets of their lives regardless of future environmental and technological changes.

For the Navy and Marine Corps, QOL is important because of its relationship to military recruitment and retention, as well as its contribution to personal readiness and performance.^{8,9,10,11,12} Positive perceptions of Navy and Marine Corps life are critical to the ability to attract and retain qualified personnel, while QOL in duty-related life domains has an important impact on individual morale, group (small unit) cohesion, and organizational esprit de corps.¹³

The Marine Corps philosophy of camaraderie, mission accomplishment, faithfulness, loyalty, and service as a daily way of living is notable in this context. This philosophy is extended to Marine Corps families through a variety of means. In-depth programs are provided prior to scheduled deployments. Family support for deployed units is provided through electronic mail, videos, commanding officers' letters, the establishment of "home support units," and other means to

⁶Parmenter, T. 1994. "Quality of Life as a Concept and Measurable Entity," *Social Indicators Research*, 33:9-46.

⁷Scarpello, V., and J.P. Campbell. 1983. "Job Satisfaction: Are All the Parts There?" *Personnel Psychology*, 36:577-600.

⁸Sadacca, R., and A. DiFazio. 1991. *Analysis of Army Family Research Program Measures of Unit Readiness*, U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, Va.

⁹Burnham, M., L. Meredith, C. Sherbourne, R. Valdez, and G. Vernez. 1992. *Army Families and Soldier Readiness*, RAND Corporation, Santa Monica, Calif.

¹⁰Kerce, Elyse W. 1995. *Quality of Life in the U.S. Marine Corps*, TR 95-4, Navy Personnel Research and Development Center, San Diego, Calif.

¹¹Coolbaugh, K. 1995. *Draft Literature Review on Measurement and Evaluation Research on Family Center Programs and Mission Outcomes*, Caliber Associates, Fairfax, Va.

¹²Koopman, M.E., and D.D. Goldhaber. 1997. *Return on Quality of Life Investment*, CRM-96-147, Center for Naval Analyses, Alexandria, Va.

¹³Manning, F. 1991. "Morale, Cohesion, and Esprit de Corps," *Handbook of Military Psychology*, R. Gal and A. Mangelsdorff, eds., John Wiley & Sons, Ltd., New York.

keep family members aware of what is happening within the operational and security constraints of the deployment. Commitment to the Marine Corps involves a family commitment to the Marine Corps philosophy and its QOL implications.

Many Navy and Marine Corps families benefit from the DOD school system operated by the DOD Education Activity (DODEA). Currently there are more than 230 schools in this system serving more than 110,000 students in kindergarten through 12th grade. Of these, 167 overseas schools in 14 countries are now participating in the recently announced Presidential Technology Initiative. This initiative, which is coordinated through the White House Office of Science and Technology Policy, intends that the DODEA schools will serve as exemplars for the use of technology in education. All schools are to have a local area network and all are to be connected to the World Wide Web, but the initiative is focused on curriculum and content. About \$20 million will be provided over the next 5 years to implement and integrate technology-based curricula into the DODEA schools. The intent is to provide DOD families with an exemplary school system solidly based on the capabilities and economies available from information technology.

Helping Service members and their families adapt to military life and cope with its unique duty and career stresses has an obvious effect on retention and readiness. Further, an organization that demonstrates that it values people is able to enhance members' connection to the institution, its missions, and other members. QOL investments are a concrete example of the value and importance that the Department of the Navy places on its people. These initiatives facilitate the level of commitment necessary for mission accomplishment and help to moderate aspects of military life stress and to sustain member well-being.

ASSUMPTIONS ABOUT THE NAVY IN THE 21ST CENTURY

As we move into the 21st century, the Navy's primary QOL challenges involve expected changes in the nature of military duties and career expectations and the impact of specific duty and career demands on personal and family life.¹⁴ Future sailors and marines will be based out of a smaller number of geographic locations, primarily in the United States rather than overseas. Most will be in combat and combat support occupational specialties, and regardless of their duty assignments, more advanced technological skills will be required of all sailors and marines. More individuals will find themselves in low-density, high-autonomy duty settings. Frequent and rapid training and operational deployments

¹⁴Naval Studies Board. 1988. *Navy 21: Implications of Advancing Technology for Naval Operations in the Twenty-First Century, Volume 1: Overview*, National Academy Press, Washington, D.C.

will be the norm, but training and educational moves will be less frequent as a result of various forms of distance learning. Military careers will typically be longer than today's 20-year norm, although the actual size of the overall career component of the force may be even less than today as a reflection of an overall smaller force. Many individuals, especially those in the Marine Corps, will still serve only one or two terms before returning to civilian life.

Although many duty-related changes will be technology driven, most career and life-style changes will continue to be determined by policy decisions. Typically, these decisions have second- and third-order effects on those to whom they apply. For example, as the Navy and Marine Corps decrease the stock of on-base housing in favor of private sector, off-base housing development and monetary entitlements, there are potential impacts on each member's sense of psychological connection to and identification with the Navy and Marine Corps as institutions.^{15,16} In addition, such changes will affect the need for and use of other human service programs.¹⁷ Where people live represents an important component of their formal and informal social interactions and subsequent group identification. Future policy and management decisions, like housing policy, need to include a broadly viewed QOL impact assessment.

IMPACT OF TECHNOLOGY

The greatest impact of technological developments will be in the performance of military duties, because it is in the operational environment that changes are expected to be most dramatic. With the prominent role that job perceptions play in the overall QOL of individuals, the Department of the Navy is presented with a number of opportunities to enhance duty QOL as these technological changes are implemented in the operational environment. Most planners believe that emerging weapons and communication technologies will enable the department to reduce overall manpower requirements. As this is accomplished, fewer people and more sophisticated methods are likely to modify the manner in which

¹⁵Defense Science Board. 1995. *Report of the Defense Science Board Task Force on Quality of Life*, Office of the Secretary of Defense for Acquisition and Technology, Department of Defense, Washington, D.C., October.

¹⁶Defense Science Board. 1996. *Achieving an Innovative Support Structure for 21st-Century Military Superiority: Higher Performance at Lower Costs*, Office of the Secretary of Defense for Acquisition and Technology, Department of Defense, Washington, D.C., November.

¹⁷Twiss, P., and J. Martin. 1997. *Family Housing: A Critical Military Quality of Life Issue*, Special Report, Military Family Institute, Marywood University, Scranton, Pa.

duties are carried out in a number of ways, including more widely dispersed work groups and fewer face-to-face interactions, duties with increased autonomy and responsibility, information inundation, and duties that are intrinsically more interesting. Each of these modifications has the potential to improve the nature of the duty environment and increase duty satisfaction, but safeguards against unintended negative consequences are required to realize these potential benefits. At the same time, new leadership skills and supervisory techniques will be demanded. For example, adequate communication networks must be available to offset any negative effects of isolation and to maintain optimal contact with peers and supervisors. These evolving 21st-century duties and duty environments must consider what military history has taught us about establishing and maintaining individual morale, unit cohesion, and organizational esprit de corps.¹⁸ As the composition of the primary group and methods of operation radically change, especially in combat environments, adherence to these military principles is critical. From a sailor's or marine's perspective, successful mission accomplishment leads to high morale¹⁹ and subsequently to a satisfying military quality of life.

Family separations because of training, operational deployments, and unaccompanied tours of duty are typically considered among the most difficult aspects of military life.^{20,21,22} The availability of improved communication technologies can help at-sea members deal with one of the major stresses of Navy life. Application of communication technologies can enhance personal QOL by allowing service members an opportunity to maintain closer contact with their families and other loved ones and to maintain meaningful participation in family life. Inherent risks of such personal communications include security issues and the introduction of home-front stress into the operational environment. Leaders must learn how to manage the use of these inevitable communication technologies without compromising the security of the mission and the performance and well-being of the service member.^{23,24}

¹⁸Manning, F. 1991. "Morale, Cohesion, and Esprit de Corps," *Handbook of Military Psychology*, R. Gal, and A. Mangelsdorff, eds., John Wiley & Sons, Ltd., New York.

¹⁹Manning, F. 1991. "Morale, Cohesion, and Esprit de Corps," *Handbook of Military Psychology*, R. Gal, and A. Mangelsdorff, eds., John Wiley & Sons, Ltd., New York.

²⁰Etheridge, R. 1989. *Family Factors Affecting Retention: A Review of the Literature*, Research Report 1511, U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, Va.

²¹Coolbaugh, K., and A. Rosenthal. 1992. *Family Separations in the Army*, U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, Va.

²²Segal, M.W., and J.J. Harris. 1993. *What We Know About Army Families* (special report for Contract DAAL03-86-D-0001), University of Maryland, College Park, Md.

²³Applewhite, L., and D. Segal. 1990. "Telephone Use by Peacekeeping Troops in the Sinai," *Armed Forces & Society*, 17(1):117-126.

²⁴Medical Follow-up Agency, Institute of Medicine (IOM). 1996. *Health Consequences of Service During the Persian Gulf War: Recommendations for Research and Information Systems*, National Academy Press, Washington, D.C.

As new technologies reshape the workplace, there is a need to ensure that the cognitive and sensory demands of complex tasks do not exceed normal human capabilities or create unmanageable levels of stress. Research and development investments in human factors technology, cognitive and physical workload assessment, and improved means for matching people to jobs and duty assignments will increase job satisfaction. Increases in job satisfaction will, in turn, lead to increases in efficiency and organizational commitment.^{25,26,27}

In the off-duty domains of life, the proliferation of currently available technology should have a positive effect on QOL. As more service members and their families gain access to the Internet and its communication capabilities, it will increase access to educational and other personal self-development programs and allow individuals to conduct personal business regardless of location.

IMPACT OF DEMOGRAPHIC AND SOCIETAL CHANGES

In conjunction with technology, a second powerful influence on overall QOL will be demographic and societal changes that determine the characteristics of Navy and Marine Corps personnel, their families, and their life-style expectations and requirements.

The demands of sophisticated technology and decision-making skills logically presuppose a better-educated military. Until there is improvement in the public education system, much of the required duty-related education and training will be acquired after enlistment. Because of the skills and skill levels required to protect its training investment, the Navy, and to a lesser degree, the Marine Corps, are expected to stress retention. The naval forces, even in an overall smaller military, are expected to consist of a greater percentage of career personnel and to be somewhat older than today's forces. In general, higher educational level produces greater QOL expectations, which in turn increases the importance of addressing QOL issues in both duty and personal life domains. Voluntary education programs, already among the most-valued QOL programs, will become more popular as the need to be career competitive increases.

An older population suggests that a larger percentage of the force will be married with children, and as the general population ages, increased numbers of service personnel will be involved with elder care responsibilities.²⁸ Both of

²⁵Efraty, D., and M.J. Sirgy. 1990. "The Effects of Quality of Working Life (QOL) on Employee Behavioral Responses," *Social Indicators Research*, 22:31-47.

²⁶Furnham, A. 1991. "Work and Leisure Satisfaction," *Subjective Well-Being*, F. Strack, M. Argyle, and N. Schwarz, eds., Pergamon Press, New York, pp. 235-259.

²⁷Harrison, M.I. 1987. *Diagnosing Organizations: Methods, Models and Processes*, Sage, Newbury Park, Calif.

²⁸Day, Jennifer C. 1996. *Population Projections of the United States by Age, Sex, Race, and Hispanic Origin: 1995 to 2050*, Current Population Reports, U.S. Bureau of the Census, U.S. Government Printing Office, Washington, D.C., pp. 25-1130.

these projections suggest that demands for QOL career considerations and QOL services for families will increase. Decisions about the services offered and the modes of delivery must take into consideration society's changing definition of family and gender-role expectations. Although the traditional two-parent family will still dominate in military society, other family types are likely to increase as they have in civilian society. Wives will continue to look to their husbands for increased equity in completing tasks associated with family life (e.g., shopping and caring for children), and men will continue to seek more opportunity to share in what have traditionally been seen as maternal role responsibilities (e.g., involvement in early parenting activities).

The number of women seeking entry into the Navy and, to a lesser degree, the Marine Corps is likely to increase as women seek new opportunities for training and education and satisfying employment opportunities and careers. Societal pressures to expand military opportunities for women will continue. Any increase in the percentage of women in the Navy and Marine Corps will require the corresponding development of specific services (e.g., health care) required to maintain an acceptable level of QOL for women.

Subjective quality of life is determined less by actual conditions than by perceptions of what is fair or expected in comparison with others who are viewed as peers or equals. The general trend toward greater reliance on housing military families in the civilian community and the outsourcing of medical and other human services provide Navy and Marine Corps personnel with increased opportunities for realistic comparisons with their civilian peers. Similarly, more joint service operations and duty assignments facilitate QOL comparisons with those in other services. Military versus civilian economic comparisons are known to be a significant factor in enlistment decisions and also to affect retention to a somewhat smaller degree.²⁹ Comparisons among military members from different services are likely to have a similar effect.

QUALITY-OF-LIFE RESEARCH

Just as it is critical for a unit leader to maintain a watch on the health, morale, and well-being of his or her sailors or marines, so also in a broader sense must military organizations be cognizant of the QOL of their members. QOL research provides the basis for an assessment of the fabric of the organization and the information required for important investment decisions that will affect the organization's future. QOL research must help guide decisions about overall allocation of resources—that is, the tradeoffs between alternative QOL programs,

²⁹Kerce, Elyse W. 1995. *Quality of Life in the U.S. Marine Corps*, TR 95-4, Navy Personnel Research and Development Center, San Diego, Calif.

and tradeoffs between QOL programs and other investments in people, equipment, research, and technology, and even in the organization's ability to carry out operational activities. Currently, we do not know whether a dollar spent on housing programs improves retention more than the same dollar spent on exchanges. We know even less about whether either of these quality-of-life expenditures improves fighting effectiveness more than an extra steaming day per quarter per ship. To support informed decision making, future research needs to improve in three basic areas: providing mechanisms for obtaining better and more timely data; developing linkages between QOL program efficacy and valid measures of performance; and establishing a broader approach to our understanding of the concept of quality of life.

Objective measures of standard of living are typically used to represent the verifiable QOL of a particular population. For the Navy and Marine Corps, examples of such measures are military pay and other service-related monetary compensation, the square footage of barracks or shipboard living space, or the average length of time to obtain an appointment to receive non-emergency health care. Historically, correlations between objective measures of QOL and individuals' overall perceptions about their QOL have been low,³⁰ which suggests that a comprehensive assessment of QOL needs to take into consideration some combination of both objective and subjective factors.

To date there is no "gold standard" in civilian or military QOL research.³¹ As Halliday notes³² in his review of Nussbaum and Sen's book *The Quality of Life*,³³ "a wide-ranging set of variables cannot be reduced to a simple indicator; there are just too many incommensurable values at stake. It is simply intuitive that the rich tapestry of human lives and the way in which people may choose, say, time with family over earned income, makes the reduction of multitudinous components to one scalar quantity both impossible and undesirable" (p. 272).

While measurement issues are obviously formidable, QOL research remains an important area of interest both because of the economic issues involved and because of the apparent linkages between QOL and various militarily relevant variables such as recruitment, retention, readiness, and personnel performance. As noted above, the Navy and Marine Corps lack a comprehensive system for tracking QOL expenditures at a detailed level. This prevents policy makers and researchers from knowing how much the Navy and Marine Corps are spending on QOL programs for various groups of sailors and marines. From a policy point

³⁰Allen, L. 1991. "Benefits of Leisure Services to Community Satisfaction," *Benefits of Leisure*, B.L. Driver, P.J. Brown, and G.L. Peterson, eds., Venture, State College, Pa.

³¹Parmenter, T. 1994. "Quality of Life as a Concept and Measurable Entity," *Social Indicators Research*, 33:9-46.

³²Halliday, R. 1995. "The Quality of Life," *Journal of Value Inquiry*, 29:269-278.

³³Nussbaum, M.C., and A.K. Sen. 1993. *The Quality of Life*, Oxford University Press, New York.

of view a comprehensive tracking system would allow the Navy and Marine Corps leadership to monitor spending at a more detailed level. From a research point of view it would allow military scientists an opportunity to examine the connection between QOL cost factors and indicators of various possible outcomes.

The Army is developing what might be considered a candidate 21st-century comprehensive, integrated, computer-based QOL information system.³⁴ In July 1996, the Army Chief of Staff directed the development of a quarterly command update that assesses broadly defined objective and subjective components of QOL. This requirement has resulted in an effort to develop an Installation Status Report (ISR), a decision support system similar to the Army's current Unit Status Report (USR). As now envisioned, the fully developed ISR will contain three QOL components: infrastructure data, environmental data, and services data. These data, when combined with various installation, Army-wide, and DOD soldier and family member survey data, will provide an opportunity to create an integrated, computer-based, comprehensive QOL information system. The potential exists for these data to be linked to other military and federal data.

If this comprehensive information management system is fully developed and integrated with other related information systems, it will provide a powerful tool for ongoing assessment of the dynamic factors that are thought to influence QOL and its relationship to a variety of militarily relevant outcomes. The system being envisioned will have the potential to provide both macro (Army)- and micro (installation)-level management and decision-making information. A similar system would be useful for the Navy and Marine Corps.

The most useful future research on QOL will connect both objective and subjective variables to militarily relevant outcomes such as actual retention, on-the-job performance, and overall duty performance, and ultimately readiness and combat performance. Currently, only a fraction of the QOL research makes the connection between the inputs and these outcomes. Most of this research has focused only on retention. Researchers need to use or to develop metrics that indicate the fighting effectiveness of the Navy and Marine Corps, and then to identify which QOL programs influence these measures of effectiveness.

Some of the basic steps along this path were developed in recent Marine Corps QOL studies.^{35,36} Structural equation models were used to demonstrate causal relationships between QOL and behavioral outcomes, including measures

³⁴Carney, C. 1997. Personal communication regarding the development of the Army's *Installation Status Report*, Caliber Associates, Fairfax, Va.

³⁵Kerce, Elyse W. 1992. *Quality of Life: Meaning, Measurement, and Models*, TN-92-15, Navy Personnel Research and Development Center, San Diego, Calif.

³⁶Kerce, Elyse W. 1995. *Quality of Life in the U.S. Marine Corps*, TR 95-4, Navy Personnel Research and Development Center, San Diego, Calif.

of readiness, reenlistment intentions, and performance. The results of this research provided empirical evidence for what military leaders have long believed, that QOL has an important payoff in desired military outcomes. The instruments and methods used in this study provide a starting point for continued monitoring of Marine Corps (and Navy) QOL and provide a mechanism to begin assessing the effects of technological, demographic, and policy changes on QOL.

Even when we are able to quantify the relationships between QOL and various militarily relevant variables, leaders will still have to weigh the potential second-order effects associated with these relationships, some of which may not be easily identified. For example, making more on-base housing available to junior enlisted families may have a positive impact on young families that often benefit from easy access to a range of military community services. Senior personnel may be attracted to the possibility of an adequate housing entitlement that allows them an opportunity to establish themselves in the local civilian community. An unforeseen second-order effect, however, might be the loss of the stabilizing maturity and community leadership that these more senior personnel bring to the on-base community. Reducing their density on base could result in a significant lowering of an installation's quality of life. Addressing these kinds of questions will require expanded program evaluation efforts and the establishment of longitudinal research studies that begin to examine a variety of military career issues.³⁷

Relationships among naval forces' members, and among member families, are critical components of overall QOL, and they need to be represented in all QOL assessments. As noted above, military leaders typically refer to these connections as unit cohesion.³⁸ The challenge for the Navy and Marine Corps involves more than just managing "collections" (compensation, benefits, and services) in a fiscally constrained environment: they must find new ways to build and sustain their members' sense of connection to the institution, its mission, and other members.

Finally, research related to QOL must take into consideration the fact that there are often recursive relationships between components of QOL and various militarily related outcomes. In the same way that successful individual and unit performance enhances morale and unit cohesion,³⁹ so also does successful individual and unit performance have direct and indirect impacts on various aspects of personal and family life. Many of the sacrifices inherent in military life take

³⁷Gade, P. 1991. "Military Service and the Life-course Perspective: A Turning Point for Military Personnel Research," *Military Psychology*, Vol. 3, pp. 187-200.

³⁸Manning, F. 1991. "Morale, Cohesion, and Esprit de Corps," *Handbook of Military Psychology*, R. Gal and A. Mangelsdorff, eds., John Wiley & Sons, Ltd., New York.

³⁹Psotka, J. "Cohesion Research: Do Cohesive Groups Win, or Does Winning Produce Cohesion?" *ARI Newsletter*, 5(4):16-17, Alexandria, Va.

on a different meaning in the context of a military promotion or a member's return from a successful combat deployment. These recursive relationships are seldom considered in current QOL research.

MEASURES OF QUALITY OF LIFE

This review highlights the fact that there is an extensive literature on objective (social indicators and program services) measures of QOL, as well as subjective measures of both overall QOL and the various life domains that reflect the idiosyncratic nature of these domains for various population groups such as military members and their families. As noted by Coolbaugh,⁴⁰ models and methods are now available for application of military and civilian QOL research to mission outcomes. Considerable investment is needed (as noted in the Army's current effort to develop the ISR) in institutionalizing reliable, valid, and readily available QOL data and management access to these data. For many military human service programs such as family services, this means developing measures of effectiveness that go beyond the current process measures (e.g., counts of program use) and actually assess the effects of the services being provided. These program data do not now exist. Since most military human service programs are comparable across the military, investment in measurement, development, and data collection methodology requires Navy and Marine Corps encouragement and DOD-level leadership.

DOD actively studies the factors that influence recruitment. The 1996 Youth Attitude Tracking Survey, which annually conducts a telephone survey of about 10,000 young men and women, reports that the percentage of males, age 16 to 24, who plan "definitely" or "probably" to enlist in the military Services dropped from 26.2 percent to 20.7 percent over the years from 1991 to 1996.⁴¹ The percentages of young men who specifically mentioned the Navy were found to be 9.9 percent in 1991 and 7.8 percent in 1996. Comparable percentages for the Marine Corps were 9.7 and 8.4. These declines were attributed to a booming economy that has increased competition from both industry and academia. Young people were found to be more likely to seek advancement through college education rather than military service. They view military service as dangerous and unpleasant, and they are unwilling to make the sacrifices in personal freedom required by military service.

More than 30 percent of first-term sailors and marines do not complete the

⁴⁰Coolbaugh, K. 1995. *Draft Literature Review on Measurement and Evaluation Research on Family Center Programs and Mission Outcomes*, Caliber Associates, Fairfax, Va.

⁴¹Hintze, D.W., P. Giambo, J.B. Greenless, T. Hagerty, M.J. Wilson, and J.D. Lehnus. 1996. *Youth Attitude Tracking Study 1996: Propensity and Advertising Report*, DASW01-96-C-0041, Item 0002BG, Defense Manpower Data Center, Washington, D.C.

first term of service,⁴² many for reasons that relate to poor screening rather than QOL issues. For those who complete their first term successfully and whose performance warrants retention consideration, QOL factors are important. Surveys have been able to document links between retention and QOL.⁴³ In a recent study,⁴⁴ survey data were matched with personnel records to determine whether satisfaction with QOL programs such as family service centers is correlated with actual (not intended) retention decisions. The study showed not only that there was a significant increase in retention, but also that the cost of these programs was far less than the cost of retention by means of reenlistment bonuses or other types of cash compensation.

Current QOL research on readiness relies on the individual's self-perception of his or her individual readiness. Unit-based measures of readiness have been severely criticized as lacking reliability, validity, and utility.⁴⁵ This includes DOD's SORTS data, the Air Force's ULTRA model, and the Army's current USR. Recently, RAND, the U.S. Marine Corps, and the Army Family Research Program conducted studies to develop theoretically and statistically sound measures of individual readiness.⁴⁶ The previously described Army QOL information system for the 21st century is attempting to incorporate components from many of these QOL readiness models. Similar efforts should be made to establish unit-based readiness and performance measures and corresponding QOL linkages.

Based on the information and arguments presented to this point, the Navy and Marine Corps need to do the following:

1. Conduct regular, comprehensive, Service-wide QOL assessments (at least every three years).
2. Expand collection of QOL program data beyond data on current process variables (staffing, funding, access, waiting times, numbers served, and so on) to include data on cost, client satisfaction, and the measurement of objective indicators of program effectiveness. The availability of these data will enhance cost-

⁴²U.S. General Accounting Office. 1997. *Military Attrition. DoD Could Save Millions by Better Screening Enlisted Personnel*, GAO/NSIAD-97-39, U.S. Government Printing Office, Washington, D.C.

⁴³Coolbaugh, K. 1995. *Draft Literature Review on Measurement and Evaluation Research on Family Center Programs and Mission Outcomes*, Caliber Associates, Fairfax, Va.

⁴⁴Koopman, M.E., and D.D. Goldhaber. 1997. *Return on Quality of Life Investment*, CRM-96-147, Center for Naval Analyses, Alexandria, Va.

⁴⁵Coolbaugh, K. 1995. *Draft Literature Review on Measurement and Evaluation Research on Family Center Programs and Mission Outcomes*, Caliber Associates, Fairfax, Va.

⁴⁶Coolbaugh, K. 1995. *Draft Literature Review on Measurement and Evaluation Research on Family Center Programs and Mission Outcomes*, Caliber Associates, Fairfax, Va.

benefit investment decisions among QOL programs and provide the data-based information required for programmatic decision making at all levels of command.

3. Develop and validate measures of readiness and performance, at both individual and organizational levels, and establish mechanisms to examine the relationships among these military outcomes and QOL factors.

4. Establish a central repository for QOL data and mechanisms that encourage military QOL research both within DOD and in DOD-Service partnerships with researchers in private-sector and academic settings.

Investments in quality of life require balance. Overconcentration on quality of life issues can adversely affect modernization and readiness if it unnecessarily deprives them of funds. On the other hand, failure to invest sufficiently in quality of life issues will harm the armed forces and increase personnel costs—personal dissatisfaction causes individuals to vote with their feet by leaving the Service. Determining an appropriate balance cannot be accomplished in a vacuum. If the above suggestions are pursued, they will go far toward providing information now needed to inform decisions on quality of life investments.

QUALITY-OF-LIFE PRIORITIES FOR THE FUTURE NAVY AND MARINE CORPS

Giving priority to the following areas will help ensure an acceptable level of quality of life for Navy and Marine Corps members and their families and, in turn, contribute to retention, readiness, performance of duty, and overall mission accomplishment:

- *Commitment and community.* Positive perceptions of Navy and Marine Corps life are critical in attracting and retaining qualified personnel, and QOL in duty-related life domains has an impact on morale and performance. The Navy should continue to encourage and develop commitment to the organization and a sense of connection to the military community by demonstrating concern for members and families through a range of QOL services. Innovative programs to build and foster commitment and community among Navy and Marine Corps families, such as the U.S. Marine Corps (USMC) Family Team Building and Community Action Process initiatives, should be encouraged. Privatizing the delivery of QOL benefits and services should be reviewed.

- *Workplace characteristics.* As new technologies reshape the workplace, there is a need to ensure that the cognitive and sensory demands of complex tasks do not exceed normal human capabilities or reasonable levels of stress. The Navy must maintain a watch for unintended consequences of technology in the workplace so as to take optimum advantage of the potential for enrichment and minimize the negative aspect of restructuring. Duty assignment is a critical QOL

component, and it requires better matching of individual capabilities and preferences with job demands.

- *Communication.* Separations due to training, operational deployments, and unaccompanied tours of duty are typically considered among the most difficult aspects of military family life.^{47,48,49} The availability of improved communication technologies should be exploited to help deployed personnel deal with one of the major stresses of Navy life and to enhance QOL by providing opportunities to maintain closer contact with families and other loved ones. Leaders must learn how to manage the use of these communication technologies without compromising the security of the mission or the well-being of the Service member.

- *Professional growth.* Because of the skills and skill levels required to protect its education and training investment, the Navy Department will increasingly stress retention and will include a greater percentage of career personnel who are both better trained and older than members of today's force. In general, higher educational levels engender greater expectations, which in turn emphasize the importance of QOL in both duty and personal life domains. The growth of military professionalism must be provided for among both enlisted and officer Navy Department personnel.

- *Research and analyses.* Regular, systematic assessment of QOL should be established and routinized. Available technology and information systems can be used effectively and efficiently to build centralized databases of demographic information that can be combined with other data to answer questions about the utility and cost-effectiveness of QOL programs. The results of these efforts should be applied to allow policy makers to make more informed decisions about tradeoffs among programs based on their utility and their contribution to mission accomplishment. Results of these efforts should also be used to strike a proper balance overall between resources allocated to QOL programs and those allocated to meet other Navy Department needs.

⁴⁷Cooke, T.W., A.J. Marcus, and A.O. Quester. 1992. *Personnel Tempo of Operations and Navy Enlisted Retention*, CNA Research Memorandum, Center for Naval Analyses, Alexandria, Va., pp. 91-150.

⁴⁸Coolbaugh, K., and A. Rosenthal. 1992. *Family Separations in the Army*, U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, Va.

⁴⁹Segal, M.W., and J.J. Harris. 1993. *What We Know About Army Families*, U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, Va.

5

Development and Maintenance of Human Performance

Invest more in people-centered research to support the introduction of new technologies and to increase efficiency.

A substantial number of new technologies will be available over the next several decades to help improve the way the Navy makes the most of its human resources. Understanding the strengths and weaknesses of these technologies and the cost-effectiveness of different approaches for using them should be an important research objective; otherwise, the technologies will enter the Navy in a piecemeal and less efficient way. Research into the cultural and organizational implications of technological change will also be important because these factors are at least as significant for effecting change as the technology itself. Systematic review of the understanding of human cognitive processes, limitations, and workload constraints should be part of this research agenda. Periodic full-system analyses will also be useful to understand the interaction among technologies and the tradeoffs among the various means for developing and maintaining human productivity.

Research in these areas, especially applied research to help organizations make choices among technologies and adapt to using new technologies, is not extensive. Clear data about what is now spent on research in this area are hard to come by; a cursory look suggests that the amounts spent may be small. For example, in FY 1996 the Department of the Navy invested only \$29 million in the two congressional budget categories associated with people-centered research relevant to training (education and training, and simulators and training devices), when the total amount spent by the Navy on residential training for individuals,

excluding the amounts spent on field and fleet training, was more than \$5 billion. Also in FY 1996, Navy Department spending on all human resources research was about \$86 million from a military work force account of more than \$23 billion. This area might be examined further, with the aim of developing an overall investment plan; the return on a research investment of this type could be substantial.

Develop a more integrated system for managing people in response to advancing technologies, in order to increase efficiency and improve readiness.

Managing human resources to produce people able to do the variety of Navy jobs entails many separate activities, among them recruiting, testing and classifying, training, and assigning personnel to fleet and other jobs, as well as managing their careers, ensuring an adequate environment for them and their families, and retaining a high percentage of them in the Navy.

Technology increasingly requires that these activities be synergistic to succeed, but organizational or cultural behavior can impede this synergy.

- Recruiting more highly capable individuals is efficient only to the extent that classifying, training, and assigning activities exploit their capabilities.
- Technological advances allowing more effective self-paced instruction are useful only if the process for assigning people can provide jobs on varying schedules and reward individuals for early completion.
- Investments in CD-ROM or embedded training possibilities are worthwhile only if the other facets of human resource management are positioned to take advantage of them.
- Technology advances over the next three decades will create opportunities to manage people more efficiently by taking better advantage of their skills, experience, and talents. For example, advances in information processing and communication technology will contribute in the following ways:
 - Provide more specific, more useful, and more timely information, enabling people to be tested, classified, and assigned with greater accuracy;
 - Create greater opportunities for distance learning, use of more effective simulators, more effective multimedia training, embedded training, and other approaches that allow tailoring of training to individual circumstances;
 - Allow better measures of productivity to be created and make people more productive;
 - Make more information available to both the Navy and the sailor for career management and provide sufficient communication capacity to allow managing careers on a more interactive basis; and
 - Enable sailors to deploy and, except when in combat, to stay in close touch with their families and other loved ones.

These changes in technology will allow more effectual management of people, to the benefit of both the Navy and the sailor, but they are likely to require greater flexibility in personnel and training organization and in decision making than currently exists. In particular, there remain serious gaps in our understanding of the tradeoffs among components of the human resource system. Research and analyses are needed to understand these possible tradeoffs and to determine how a new human resource management system might be created that exploits the advantages of the new technologies and results in greater efficiency in the employment of people and higher levels of readiness.

Research and analyses of this sort are generally insufficiently funded, but information and communication technology are advancing in ways that will make the collection of relevant data simpler and less expensive, and planning for collecting and exploiting these data ought to begin now. The return on this small investment is likely to lead to better decisions and greater efficiencies in the future.

It should be recognized that human competence is essential to every Navy and Marine Corps operation. Its presence will not guarantee the success of these operations, but its absence will most certainly ensure their failure. The availability of human performance at the highest practicable levels of competence is a matter of first importance to the Navy. Investments in human resources that are modest compared to other areas will yield substantial returns. They should be treated as significant issues that deserve both priority and high-level attention.

APPENDIXES

A

Terms of Reference



CHIEF OF NAVAL OPERATIONS


28 November 1995

Dear Dr. Alberts,

In 1986, at the request of this office, the Academy's Naval Studies Board undertook a study entitled "Implications of Advancing Technology for Naval Warfare in the Twenty-First Century." The Navy-21 report, as it came to be called, projected the impact of evolving technologies on naval warfare out to the year 2035, and has been of significant value to naval planning over the intervening years. However, as was generally agreed at the time, the Navy and Marine Corps would derive maximum benefit from a periodic comprehensive review of the implications of advancing technology on future Navy and Marine Corps capabilities. In other words, at intervals of about ten years, the findings should be adjusted for unanticipated changes in technology, naval strategy, or national security requirements. In view of the momentous changes that have since taken place, particularly with national security requirements in the aftermath of the Cold War, I request that the Naval Studies Board immediately undertake a major review and revision of the earlier Navy-21 findings.

The attached Terms of Reference, developed in consultation between my staff and the Chairman and Director of the Naval Studies Board, indicate those topics which I believe should receive special attention. If you agree to accept this request, I would appreciate the results of the effort in 18 months.

Sincerely,


J. M. BOORDA
Admiral, U.S. Navy

Dr. Bruce M. Alberts
President
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Enclosure



TERMS OF REFERENCE

TECHNOLOGY FOR THE FUTURE NAVY

The Navy-21 study (Implications of Advancing Technology for Naval Warfare in the Twenty-First Century), initiated in 1986 and published in 1988, projected the impact of technology on the form and capability of the Navy to the year 2035. In view of the fundamental national and international changes -- especially the Cold War's end -- that have occurred since 1988, it is timely to conduct a comprehensive review of the Navy-21 findings, and recast them, where needed, to reflect known and anticipated changes in the threat, naval missions, force levels, budget, manpower, as well as present or anticipated technical developments capable of providing cost effective leverage in an austere environment. Drawing upon its subsequent studies where appropriate, including the subpanel review in 1992 of the prior Navy-21 study, the Naval Studies Board is requested to undertake immediately a comprehensive review and update of its 1988 findings. In addition to identifying present and emerging technologies that relate to the full breadth of Navy and Marine Corps mission capabilities, specific attention also will be directed to reviewing and projecting developments and needs related to the following: (1) information warfare, electronic warfare, and the use of surveillance assets; (2) mine warfare and submarine warfare; (3) Navy and Marine Corps weaponry in the context of effectiveness on target; (4) issues in caring for and maximizing effectiveness of Navy and Marine Corps human resources. Specific attention should be directed, but not confined to, the following issues:

1. Recognizing the need to obtain maximum leverage from Navy and Marine Corps capital assets within existing and planned budgets, the review should place emphasis on surveying present and emerging technical opportunities to advance Navy and Marine Corps capabilities within these constraints. The review should include key military and civilian technologies that can affect Navy and Marine Corps future operations. This technical assessment should evaluate which science and technology research must be maintained in naval research laboratories as core requirements versus what research commercial industry can be relied upon to develop.

2. Information warfare, electronic warfare and the exploitation of surveillance assets, both through military and commercial developments, should receive special attention in the

review. The efforts should concentrate on information warfare, especially defensive measures that affordably provide the best capability.

3. Mine warfare and submarine warfare are two serious threats to future naval missions that can be anticipated with confidence, and should be treated accordingly in the review. This should include both new considerations, such as increased emphasis on shallow water operations, and current and future problems resident in projected worldwide undersea capability.

4. Technologies that may advance cruise and tactical ballistic missile defense and offensive capabilities beyond current system approaches should be examined. Counters to conventional, bacteriological, chemical and nuclear warheads should receive special attention.

5. The full range of Navy and Marine Corps weaponry should be reviewed in the light of new technologies to generate new and improved capabilities (for example, improved targeting and target recognition).

6. Navy and Marine Corps platforms, including propulsion systems, should be evaluated for suitability to future missions and operating environments. For example, compliance with environmental issues is becoming increasingly expensive for the naval service and affects operations. The review should take known issues into account, and anticipate those likely to affect the Navy and Marine Corps in the future.

7. In the future, Navy and Marine Corps personnel may be called upon to serve in non-traditional environments, and face new types of threats. Application of new technologies to the Navy's medical and health care delivery systems should be assessed with these factors, as well as joint and coalition operations, reduced force and manpower levels, and the adequacy of specialized training in mind.

8. Efficient and effective use of personnel will be of critical importance. The impact of new technologies on personnel issues, such as education and training, recruitment, retention and motivation, and the efficient marriage of personnel and machines should be addressed in the review. A review of past practices in education and training would provide a useful adjunct.

9. Housing, barracks, MWR facilities, commissaries, child care, etc. are all part of the Quality of Life (QOL) of naval personnel. The study should evaluate how technology can be used to enhance QOL and should define militarily meaningful measures of effectiveness (for example, the impact on Navy readiness).

10. The naval service is increasingly dependent upon modeling and simulation. The study should review the overall architecture of models and simulation in the DoD (DoN, JCS, and OSD), the ability of models to represent real world situations, and their merits as tools upon which to make technical and force composition decisions.

The study should take 18 months and produce a single-volume overview report supported by task group reports (published either separately or as a single volume). Task group reports should be published as soon as completed to facilitate incorporation into the DoN planning and programming process. An overview briefing also should be produced that summarizes the contents of the overview report, including the major findings, conclusions, and recommendations.

B

Acronyms and Abbreviations

A	Basic training (school)
AFQT	Armed Forces Qualification Test
ASVAB	Armed Services Vocational Aptitude Battery
ASW	Antisubmarine warfare
AW	Aviation antisubmarine warfare (operator)
CAD	Computer-aided design
CBI	Computer-based instruction
CNO	Chief of Naval Operations
COMMS	Communications
CONUS	Continental United States
DITIS	Defense Instructional Technology Information System
DOD	Department of Defense
DODEA	Department of Defense Education Activity
DVD	Digital videodisk
GED	General equivalency diploma
HSDG	High school diploma graduate
IMAT	Interactive multisensor analysis training
IMIS	Integrated Maintenance Information System
ISR	Installation Status Report

IVI	Interactive videodisk instruction
MMTR	Military Manpower Training Report
MOPP	Mission-oriented protection posture
MPN	Military personnel-Navy
MWR	Morale, welfare, and recreation
O&M	Operation and maintenance
OPS	Operations
PERSTEMPO	Tempo of personnel deployment
POM	Program objectives memorandum
PQS	Performance qualification standard
QOL	Quality of life
R&D	Research and development
SORTS	Status of Resources and Training System
STG	Sonar technician-guns
STS	Sonar technician-systems
USMC	U.S. Marine Corps
USR	Unit Status Report

DTIC QUALITY INSPECTED 4